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AD366698
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TECHNICAL INSPECTION REPORT

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Classification (Cancelled) (Changed to Security Information)
By Authority of JOINT CHIEFS OF STAFF JCS 1795/36 DATED 15 APRIL 1949
By John H. Vayette Date 18 SEP 1953

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TECHNICAL INSPECTION REPORT

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WELDING

SECTION I - GENERAL

Because of the important part welding plays in present day ship construction, and the even greater role in prospect for this fabrication process in the building of future ships of the United States Navy, special effort was made to obtain as much information as possible on the performance of welded construction on the target ships subjected to the atomic bomb burst at Operation Crossroads.

The expressed object of this phase of inspections performed under the Direction of Ship Material was to determine the effects of the operations on welding and welding equipment; welds in ship's hulls, ship's machinery and submarines; and if possible, to determine and correlate the origin and cause of weld failures with geometry of structure, joint designing material, welding procedure, and weld quality.

The results of both Test A and Test B are covered in this report. To help in differentiating between Test A damage and Test B damage it can be generally assumed that damage due to underwater shock is to be associated with Test B and damage from air blast occurred as a result of Test A.

The target array in both tests included ships of riveted construction and others in which fabrication by welding had been extensively employed. Of the combatant vessels in the two test arrays, excluding the ex-German Cruiser PRINZ EUGEN and the USS INDEPENDENCE, the heavier ships were essentially of riveted construction. The four classes of destroyers represented in the tests were of part riveted and part welded design, while the submarines and landing craft were fabricated almost completely by welding. Approximately twenty APA transports of the Gilliam Class in the target array were of welded construction. Seams in shell plating above the bilge were riveted.

WELDING

SECTION II

EFFECTS OF WELDING PROCESS

It was realized in the early stages of planning that the explosion, in addition to the creating blast and shock waves would emanate strong radiations. Accordingly, it was considered desirable to ascertain, if possible, the effects of such radiations on ship materials to be welded on welding circuits, and on supplies such as electrodes, fuel gases, etc. to be used in the welding process. It was understood that accurate determinations concerning such effects would likely be beyond the scope of facilities available at the test site, but that functional tests made aboard target ships during inspections using target ship materials and equipment might furnish some clue of changes resulting from such effects, if present. Actually, observations of this nature were very limited as a result of the necessity for strict adherence to safety regulations. It is possible to say, however, that temporary repair welds made on target ships after Test A did not indicate any abnormal occurances during gas cutting operations prior to welding or in the welding operation which followed. All welds made with equipment and materials which were believed to have been exposed to radiations to at least some degree were entirely normal in appearance.

WELDING

SECTION III

EFFECTS OF WELDING EQUIPMENT

(a) Arc welding machines were below deck in most cases or were protected from the air blast in Test A by compartment bulkheads. Those few which were on deck, none of which were exposed to severe blast, were apparently undamaged. It would appear, from observations of similar electrical equipment in Test A that the concentrated mass presented by the type of welding machines used aboard ship is relatively immune from damage from air blast unless it should be located very near to the blast source.

Although no apparent damage to arc welding equipment was observed it is quite likely that the severe underwater shock accompaning the explosion in Test B may have damaged armatures, rotors, bearings and assembly bolts in the generators and motors of this equipment. The operation of such equipment to determine whether or not such damage had occured was not practical as no power was available on the target ships after Test B.

(b) Welding cable, electrode holders, hose and torches. These materials were either stowed below decks or protected from blast by compartment bulkheads. Hence, only secondary damage due to fires in compartments where such equipment was stowed was observed.

(c) Oxygen, acetylene and other gas cylinders. In most cases gas cylinders were stowed on weather decks. In many instances, such as shown in photographs 1867-2, 1868-3 and 2116-12, pages 22, 23 and 65, cylinders were displaced from stowage racks by the force of air blast against structures to which they were secured. Similar occurrences were observed on Test B target ships moored close to the bomb. Displacement of cylinders in this test was caused by underwater shock. As far as could be ascertained displaced cylinders were undamaged.

An acetylene cylinder stowed on the weather deck of a transport was destroyed by fire in an adjacent compartment which

eventually overheated the bulkhead to which the cylinder was secured and caused the cylinder to explode. See photograph 1823-2, page 81 Cylinders in the shipfitters shop in the after superstructure of the INDEPENDENCE were destroyed by fire, although none exploded. No attempt was made to determine whether or not these cylinders were empty.

WELDING

SECTION IV

EFFECTS OF WELDS

In addition to observations made relative to the general performance of welds, effects was made to determine the origin of fracture and causes of failures occurring in way of welds with respect to geometry of structure, joint design, materials, welding procedures and weld quality.

It was usually possible to reliably determine the origin of fracture, where welded structure had failed, by a simple geometric analysis of the structure and the manner in which it was loaded. In certain instances it was possible to check such determinations by the examining fractures for herringbone patterns which indicate the general direction of propagation of the fracture from the origin. In thinner sections, where the number of fractures was greatest, a pattern was not discernible. Neither were such patterns discernible in fractures which occurred in welds. In these cases analysis of the structure and the manner of loading employed were used in determining the approximate origin of fracture. Practically all of the fractures in thin plating appeared to be of a ductile nature. A few fractures in heavier sections appeared to signify brittleness. Others were not sufficiently open to permit examination of the edges of the fracture.

Failures due to improper plate edge preparation, faulty welds resulting from poor workmanship or from poor fit up were in most cases easily recognized.

Decision as to whether defective welding materials or base materials played any part in failures was difficult, as facilities for such determinations were not available.

No failures were observed which could be definitely attributed to improper joint design. However, there were indications in certain structures that geometric discontinuities embodied in the overall

design of structure were responsible, in part, for the poor performance of certain welded connections under the loading conditions imposed by the tests.

Most of these were in unfaired connections at the intersection of structural members. Such intersections constitute stress raisers under the conditions of loading imposed in Test A. Other evidence of stress raisers in design was found where thin members were joined to heavier members.

In the discussion which follows, failures, in which welding was considered to be a contributing or influencing factor, are described in the text or illustrated by photographs. The discussion is limited to the typical and more important failures observed. The cause of failure, as accurately as could be determined under the conditions prevailing at the time of inspection are indicated. The findings of the diving group which inspected the vessels sunk in the tests are covered in a special report. The discussion is presented under three general classifications, Hull, Machinery and Submarines. Sub-items under these general headings deal with damage in way of welds in component parts of the applicable structures and assemblies.

A. HULL.

1. Shell.

(a) Failure occurred along welded butts and seams in shell plating on the USS INDEPENDENCE as shown in photographs 2216-2, 2216-7, 1733-11, 1734-1, 2114-1, 2117-10 and 2117-11, pages 35, 36, 37, 39,,40, 43 and 44. Certain of these failures occurred in the welds while others occured in the plate material adjacent to welds. Incomplete weld penetration of the joint caused failure in the former cases, and slight undercut at the edges of the welds contributed to failure in the latter cases. Shell plating in the area of greatest damage varied from 12 to 15 pounds in weight.

No failures ~~were~~ observed in composite riveted and welded joints.

There was opportunity to compare welded joints in shell plating with riveted joints.

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2. Decks.

In general decks of welded construction performed very satisfactorily. Severe deflection of such structures as a result of air blast was observed on several vessels. Photographs 2086-4, 2086-5 and 2086-8, pages 83, 84 and 87 show deflection in deck plating welded by submerged arc. No failures were observed.

Although the main and second decks aft on the INDEPENDENCE were severely deformed on the port side in way of the severely damaged area, as shown in photographs 2216-2, 2216-7, 2071-1, 2116-12, 2041-7 and 2116-7, pages 35, 36, 64, 65, 68 and 70, no failures were observed in welds. Photographs 2040-2 and 2226-12, pages 48 and 50 show deflection of the all welded hangar deck. No failures were found in welds in this deck. In the forward elevator pit on the INDEPENDENCE a failure occurred in a weld in a make up joint in a flush patch in the main deck. Examination of the fracture revealed that the joint edges of the 20 pound plate had not been beveled for welding with a result that very little of the joint was penetrated by the weld. Photograph 2100-4, page 49 shows the fracture which is approximately 6 1/2 feet long. No failures were observed in welds in STS deck plating.

3. Superstructure.

Damage to the superstructure on the INDEPENDENCE aft of the hangar space was severe. As shown in photographs 2216-2, 2216-7, 1734-1 and 2114-1, pages 35, 36, 39, and 40 there were numerous failures in side plating which followed welding seams. Certain of the failures occurred in the welds where incomplete joint penetration was observed. Others followed the seams in the plate material adjacent to the welds, and in certain cases appeared to have been caused by slight undercut at the edges of welds.

On the USS CRITTENDEN, as shown in photographs 2102-2, 2058-6, 2058-4 and 1782-1, pages 89, 90, 91 and 92 air blast from Test A caused failures in austenitic welds in STS bulkhead plating. In most of these failures lack of edge preparation for welding, incomplete joint penetration, or welds of insufficient size constitute the principal causes of failures. These were also the primary causes of weld

failures in the superstructure on the submarine SKATE as shown in photographs 1753-3 and 1752-12, pages 95 and 98 . On the SALT LAKE CITY welds joining deck house bulkheads to bulkhead bounding angles failed as shown in photographs 1729-2 and 1782-4, pages 25 and 26 . Examples of failures in way of intermittent weld in deck house bulkheads are shown in photographs 1868-4 and 1782-5, pages 27 and 28.

Photograph 1861-1, 1783-2, 1782-12, 2135-3, 1782-11 and 2094-8, pages 29, 30, 31, 32, 33, and 34 show brittle fractures which originated in the weld heat affected zone of the base material of the after tripod legs of the foremast structure. The welds were of austenitic chromium-nickel steel composition. It appears from the nature of the fractures that the tripod leg material is low alloy steel or steel of relatively high carbon content and of questionable weld ability. No thermal cracks were observed. The upward thrust from reflected blast against the bottom of the range finder platform caused the welds joining the cantilever brackets to the tripod legs to be highly stressed.

Welded connections joining the conning tower structure on the INDEPENDENCE to the flight deck structure showed no failures.

4. Hull Castings, Struts, Stern Frames, Skegs, Etc.

Except in the case of the destroyer USS HUGHES which was the only ship docked for inspection at Bikini no observations of these items were made. It is improbable that any damage covering such items was inflicted by Test A. Test B may account for some damage to such items due to severe underwater shock imparted to the shells of vessels close to the explosion. On dry docking the HUGHES, examination of the underwater body showed severe dishing of the skeg, rudder and shell plating between framing. No weld failures were observed. Struts and strut connections appeared to be undamaged.

5. Armor.

No damage was observed to welded connections to armor belts, barbettes, conning towers or armored trunks as a result of either Test A or B.

It is quite probable, however, that bolted connections in armor, barbettes and conning towers were severely strained and in certain cases partly sheared as a result of the severe shock imparted to the ship and the considerable inertia afforded by the mass of these heavy structures.

6. Turrets and Gun Shields.

There were no welds in turrets on the target ships. Damage to bolted and riveted connections in turret structures are covered in a separate report on the subject.

Welded attachments to turrets were undamaged. Ammunition handling equipment is covered in a separate report. However, no damage was observed to welds in such structure.

Gun shields and bulwark exposed to blast in Test A were severely damaged. Photographs 1734-8 and 2165-11, pages 60 and 79 show typical damage to such structure. Joints in STS material in gun bulwarks, which were welded with chromium-nickle austenitic steel electrodes failed, in many cases. In many instances incomplete weld penetration due to a lack of sufficient back chipping on such joints contributed in a major degree to such failure.

7. Elevator Structures.

The elevators on the INDEPENDENCE were of the inboard type and were carried away by air blast in Test A. The SARATOGA was too far from the blast to be seriously affected in Test A. She sank as a result of damage sustained in Test B. Underwater examinations conducted by divers are covered in a special report.

8. Structural Attachments.

(a) Transverse and longitudinal framing in deck and shell structures sustained considerable damage as a result of air blast from the Test A burst. Numerous weld failures occurred.

Photographs 2086-5 and 2086-8, pages 84 and 87 show satisfactory performance of welded deck structures on the USS CRITTENDEN. Transverse beams and deck longitudinals exhibited no failures in butts or connecting welds despite the severe deformation suffered by the structure. On the INDEPENDENCE the main deck transverse beam at frame 122 failed in a welded butt at the intersection of the beam and port side deck longitudinal Number 3. The fracture originated in the weld, which was of inferior quality, and extended on up through the web of the beam and the collar plate covering the notch for the longitudinal. Examination of the fracture revealed that the joint had been poorly fitted prior to welding and that a "dutchman" was used to fill up the gap to avoid refitting the joint. A similar failure occurred in a butt weld in a port main deck longitudinal at about frame 47 in way of the forward elevator pit, the bottom of which was severely deflected by air blast which penetrated the hangar. Incomplete joint penetration as a result of insufficient back chipping is considered to have caused the failure. Although deep longitudinals and floors supporting the hangar deck were deformed as a result of the deflection of the deck by blast, no weld failures occurred. Longitudinals and transverse beams in the main, second and poop deck structures on the port side, aft, although severely deformed by the horizontal component of the blast, revealed no significant weld failures. See photographs 2216-2, 2216-11, 2071-1 and 2114-11, pages 35, 38, 64 and 72.

Shell framing on the INDEPENDENCE on the port side, aft, in way of the severe Test A damage exhibited many weld failures. Photographs 2216-2, 2216-11 and 1734-1, pages 35, 38, and 39, show outboard views of damage to transverse framing. Frames failed at the overhead connections on the third deck and also at the third deck line due to the violent inward movements of the shell. Fillet welds of insufficient size at intercostal connections to the third deck contributed to the failures. Web frame 89, second deck, port, is fractured adjacent to austenitic welds joining the web to the STS stringer strake of the main deck, overhead. Failure occurred as a result of the strong upward pull exerted by the flight deck bent on stringer strake directly over this web. The fracture appeared to be in the web material rather than in the weld, as shown in photographs 2088-7 and 2164-2, pages 62 and 63. Photographs 2071-1 and 2116-12, pages 64 and 65 show weld failures in mid - height shell stringers and shell frames on the second and third decks respectively. At frame 110, third deck, port, the welds connecting

the web of the frame to the deck failed as shown in photographs 146-4 and 146-5, pages 66 and 67 . Undersize welds were responsible for the failure.

(b) Flight Deck Bents.

Bents supporting the flight deck were fabricated from heavy I-beams by welding. Except for the flexible wobble bents on either side of the flight deck expansion joints in the deck bents were connected to the STS sheer and stringer strakes at the main deck by austenitic welds. The force of the blast which penetrated the hangar caused the deck structure to be bulged upward, deforming the flight deck bent girders and fracturing the centerline butts and bracketed overhead connections, port and starboard, as shown in photographs 2226-12, 2222-12, 4149-5, 2226-11, 4148-11, 2226-10, 4160-10 and 2222-11 and 2226-1, pages 50, 51, 52, 53, 54, 55, 57 and 58 and 56. It will be noted that fractures in the overhead bracket connections, generally speaking originated in or at the toe of fillet welds joining the flange of the bracket to the flange of either the transverse girder or the column. The comparatively abrupt change in direction in the structure at these points constituted stress raisers under the loading conditions which prevailed during the blast. The herring-bone pattern, shown in photograph 4149-5, page 52 points to the origin of fracture in the column member, at the left in the photograph, adjacent to the fillet weld joining the bracket and column flange. A similar failure is shown in the transverse girder, starboard, at frame 77, in photograph 4148-11, page 54 . Photographs 2226-1 and 4160-10, pages 56 and 57 show failure of fillet welds connecting the bracket and transverse girder of flight deck bent 83, starboard, to the flight decks bent column. The latter photograph shows the undersize welds at this connection. The working drawings of these connections specified full penetration welds designed to develop 100 percent joint efficiency. Actually, all weld failures of this type at the port and starboard overhead connections revealed no edge preparation of structural members prior to welding. Web sections of such members were either 5/8 inch or 7/8 inch in thickness. Fillet welds joining such members were in some cases only 3/16 inches in size. At frame 65, port, the overhead connection failed in the fillet weld joining the flanges of the bracket and column. The failure shown in photograph 2222-11, page 58 , originated in the weld and propogated outboard into the web of the column.

At frame 89, in way of the fracture in the web frame on the second deck, described above and shown in photograph 2088-7, page 62 , the port flight deck bent column connection to the STS sheer strake at the main deck failed in the austenitic weld as shown in photographs 4162-2 and 959-1, pages 59 and 61, outboard and inboard views, respectively. Improper edge preparation was indicated in the failure at the sheer strake connection. Photographs 2226-11 and 2226-10, pages 53 and 55 , show failures in way of welded centerline butt joints in the flight decks bent transverse girders. Many such failures at these points indicated a lack of proper edge preparation with the result that complete penetration was not obtained. Photographs 2040-10 and 2164-7, pages 46 and 47 , show failures in welds in centerline butts in flight deck transverse boundary channels at the expansion joints. Failures of this nature occurred at frames 63 1/2, 84 1/2 and 110.

(c) Stanchions.

On several of the target ships failures were observed in welds joining pipe stanchions to overhead structure deflected downward by air blast. These failures appeared to be insignificant as stanchions failed by buckling before weld failures took place.

(d) Structural Bulkheads.

Welds in structural bulkheads, with the exception of those joining the bulkheads to decks, performed very satisfactorily. The latter failures, however, were comparatively numerous, and resulted, apparently from the failure of undersize welds. Failures of this nature are shown in photographs 2041-7 and 2114-11, pages 68 and 72. Welds attaching stiffeners to bulkheads performed very satisfactorily as shown in photographs 2114-1, 2216-5, 2227-11, 2086-6 and 2195-7, pages 40, 42, 69, 93and 112.

End-welded pins securing fibre glass insulation to bulkheads performed very satisfactorily under the air blast in Test A. See photographs 2100-8, 2100-4, 146-4, 2227-11 and 2116-7, pages 45,49, 66, 69, and 70. An instance of failure of end-welded insulation pins is shown in photograph 2058-4, page 91 . The bulkhead material in this case was STS plate.

Note in the same photograph that pins on the adjacent panel are still securely attached. The performance of pins securing insulation to the overhead in way of a deck severely deflected by air blast is shown in photograph 2086-8, page 87.

On the USS FALLON which was subjected to severe underwater shock in Test B, end-welded insulation pins performed satisfactorily as shown in photographs 2195-7 and 2196-7, pages 112 and 113.

(e) Hatches and Doors.

No failures were observed in welds in doors, hatches or hatch covers. In both tests particular attention was given to the inspection of hatch corners for cracks and fractures. Inspections were carried out before Test A, after Test A and after Test B. In all, more than a dozen ships were examined for such failures. No failures of any type were found in these locations. The hatch corners in way of the forward and after holds on these ships were reinforced with a 2 inch halfround attached to a web plate which fitted into the hatch corners where it was securely welded into the structure. The halfround was formed concave to a radius of approximately 18 inches and was faired into the edges of the hatch opening at the hatch corners to break up the geometric discontinuity which otherwise results.

(f) Ventilation.

Ventilation trunks and ducts penetrated by blast or subjected to blast externally were seriously damaged. In general, arc welded construction is superior to riveted or crimped construction. However, in cases where internal pressure from air blast was encountered, arc welds at corner joints failed as a result of high tensile stresses set up at the root of the weld. Failures of this type are shown in photographs 2133-8 and 2133-10, pages 76 and 77. It was particularly interesting to note that resistance spot and seam weld in ventilation ducts performed very satisfactorily. As an illustrative case the resistance welded duct shown in photograph 2133-1, page 78 was severely bulged but did not fail. Other views of damage to ducts and connections in ducts are shown in photographs 2114-10, 2118-2, 2114-6 and 2086-5, pages 41, 74, 75 and 84.

B. Machinery.

1. Piping, valves and fittings.

Due to the fact that most piping was below decks and protected by hull structure very few failures occurred in pipe lines, fittings and valves in Test A. In photograph 2226-1, page 56 a failure in a weld joining an elbow to a vertical run in a sprinkler line on the starboard side of the INDEPENDENCE in the hangar space is shown. A similar failure took place on the port side. These joints were welded from the outside only without using backing strips. A weld neck flange failed in a water line in the ship fitters shop. See photograph 2041-7, page 68. A similar failure was observed in weld joining a flange to a pipe on the second deck as shown in photograph 2117-1, page 71.

As a result of shock in Test B several main steam lines were torn loose from hangars and sagged appreciably. Due to lack of sufficient time to remove lagging during the conditions prevailing after Test B thorough inspections could not be made. No failures in welds in these lines were observed. Due to the comparative flexibility in pipelines, joints where pipes pierced bulkheads performed very satisfactorily. No evidence of loss of watertight integrity in way of such joints was found. The same can be said of through joints for electric cables.

No comparison of performance of carbon molybdenum piping versus carbon steel or bain steel piping was obtained due to the difficulty presented by removing lagging and the limited time available to make inspections after Test B.

2. Fittings.

The comments under 1 above also apply to fittings.

3. Turbines.

Inspection of turbines was limited to external examination. The intervening shell and deck structures protected engineering spaces from air blast in Test A.

In Test B, however, severe damage was sustained to cast iron turbine casings and supporting feet as a result of underwater shock. Fractures on the USS FALLON in casings cast in this material are shown in photographs 4225-12, 4225-8 and 1690-11, pages 101, 102 and 103. Similar failures on the PENSACOLA due to shock are shown in photographs 4226-1, 2, 3, 5 and 6, pages 107, 108, 109, 110 and 111.

No failures were observed in cast steel casings.

4. As far as could be determined welds in boiler drums and connections were undamaged by Test A and B. As a result of air blast which penetrated boilers through stacks and uptakes, boiler casings were severely damaged. Most of the failures took place in riveted and bolted joints. No weld failures were observed.

5. No damage was observed in way of welds in pumps, condensers, evaporators, deaerators or other auxiliary machinery.

6. No weld failures were observed in gear cases or other machinery housings.

7. No damage was observed in welds in diesel engines.

8. Propellers were not observed, except on the USS HUGHES. Examination of her propellers made while the ship was drydocked revealed no damage, although she was within the shock damage radius of Test B.

9. No failures were observed in repair welds in cast iron machinery.

10. No failures were observed in welds in pressure vessels in general.

C. Submarines.

Damage to submarines as a result of Test B are covered in structural, machinery and electrical reports on these vessels. The only submarine to suffer appreciable damage in Test A was the USS SKATE. Practically all of the damage in way of welds was topside and external to the pressure hull.

A general view of this damage, due to air blast is shown in photograph 1753-3, page 95 . Most of the damage inflicted was to the conning tower superstructure, weather deck framework, and outboard piping.

1. Pressure hull.

There were no failures in welded joints in the pressure hull plating. The only weld failure found in hull framing is shown in photograph 2011-9, page 96. Here, a fillet weld joining the pressure hull and the after edge of the flange of a circumferential frame failed. The pressure hull in this area has been deflected downward slightly. The failure is about 8 inches long.

2. A weld joining the periscopes shears housing to a bolted flange failed as shown in photograph 1751-11, page 97.

3. Typical failures in austenitic welds in STS superstructure plating are shown in photograph 1752-12, page 98 . Some of the fillet welds at such connections appeared to be small, and there was considerable evidence of incomplete weld penetration in butt joints in STS plating. The latter deficiency is considered to have resulted from insufficient back chipping of joints.

4. Piping.

Silver brazed joints in salt water cooling line fittings, sustained severe damage due to air blast. Copper-nickle tubing in these lines had, in several cases, pulled out of the sockets due to failure of the brazing material. Photographs 2057-6 and 2057-11, pages 99 and 100 show the nature of these failures. Examination of the separated joints revealed incomplete penetration of the brazing alloy into the joint. Obviously workmanship on the part of the brazing operator was at fault.

Photograph 2057-6, page 99 shows a failure in a porous silicon bronze weld joining a fitting to a fabricated outboard induction valve.

WELDING

SECTION V - CONCLUSIONS

1. In general, the overall performance of welded construction in target vessels subjected to the atomic bomb explosions at Bikini was very satisfactory. There were, however, enough weld failures to warrant certain conclusions as to which types of defects are to be more commonly expected in naval construction and the influence these defects have on the performance of structures and assemblies under blast and shock loading. It was also possible to draw general conclusions as to the affects of geometry of structure on failures in way of welded connections. It was also possible to assess roughly the relative effects of the various factors influencing weld quality.

A list of the more significant conclusions relative to the effects of the tests on welded construction are as follows:

(a) Welding materials and equipment appear to have been unaffected by radiations emanated by the bomb. If changes have been effected they do not appear to influence the welding process or the resulting welds.

(b) Shock and blast damage to welding machines and gas cylinders was not appreciable. In the case of cylinders, however, consideration should be given to providing suitable protective shelter from blast to cylinder stowage spaces. The design of stowage racks should be improved to hold the cylinders more securely in place.

(c) A relatively large number of failures occurred in way of geometrical discontinuities at connections in important structure. More extensive application of connections embodying faired design is indicated.

(d) Materials in general appear to have performed very satisfactorily. Misuse of materials appear to have been a factor in a few of the failures observed. The results of tests being conducted at the Engineering Experiment Station under Test No. C-2853, when available, may help in determining whether or not materials played any part in these failures.

(e) Instances where the use of improper welding procedures may have contributed to failures were limited.

(f) Weld quality, without question, appears to have been the most important factor in the performance of welded structure. This statement is made in the sense that weld quality covers plate edge preparation, fitting, shipping and welding. A very large percent of the failures observed, appear to have resulted from a lack of edge preparation of members prior to welding. Improper back chipping in connection with welding, particularly on thin STS plating, appears to have been responsible for many of the failures observed in gun bulwarks and STS bulkheads, etc. Poor fitting and the unauthorized use of "slugs" and "dutchman" in a few cases contributed materially to failures in important structural members. Obviously, the way to prevent the occurrance of these defects lies in placing greater emphasis on inspection of joints before welding. Closer inspection after welding will prevent undersize welds from occurring in structure.

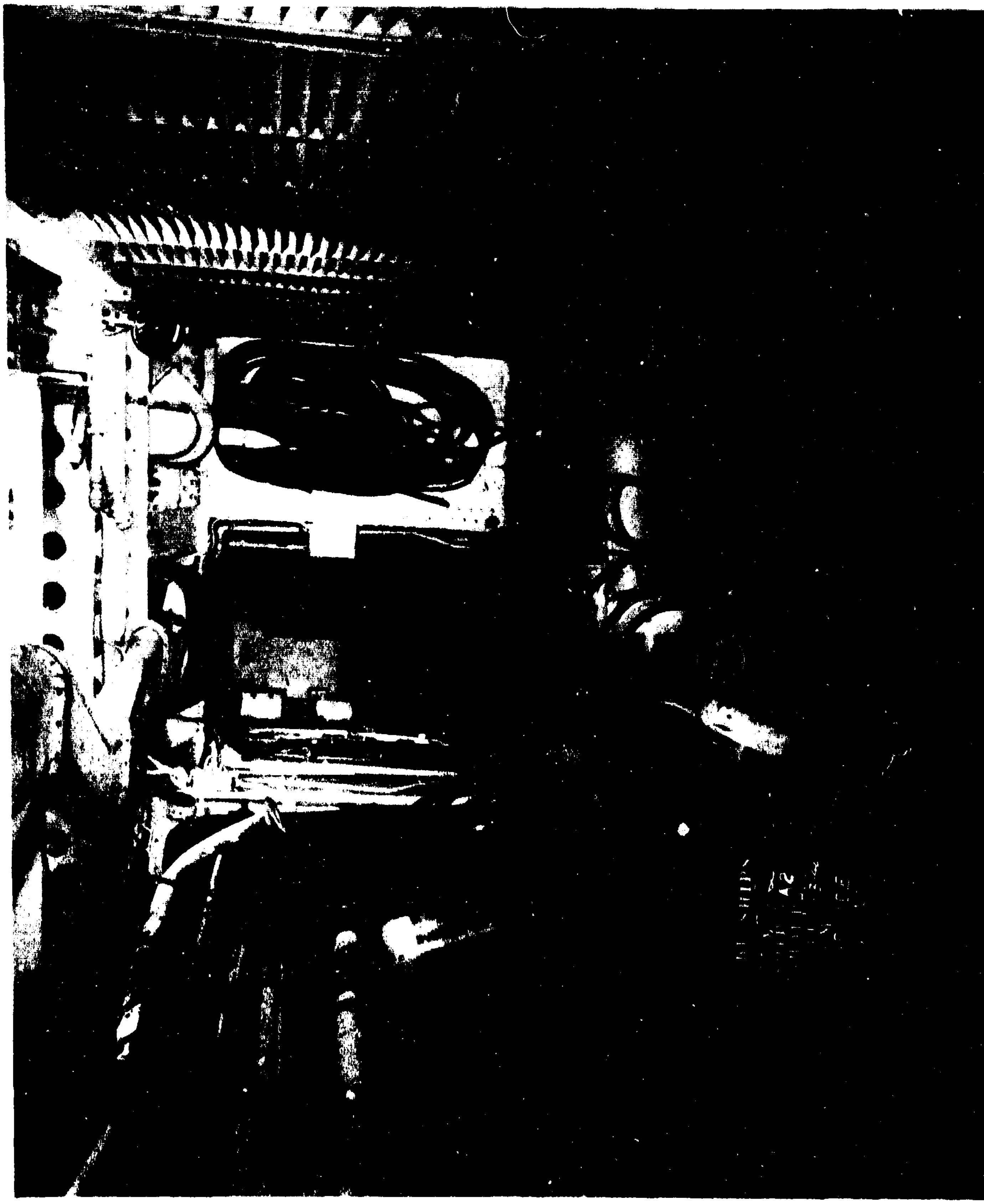
(g) Failures in brazed joints on submarine salt water lines indicated that more emphasis should be placed on frequent periodic requalifications of brazing operators. The development of tests to evaluate the resistance of brazed pipe joints to blast and shock loading is indicated. Such tests would be helpful in excluding brittle brazing alloys from applications in Naval Service.

(h) Cast iron ships machinery is verys susceptible to fracture under shock loading. The performance of cast steel and fabricated steel machinery was very superior in this respect.

SECTION VI

PHOTOGRAPHS

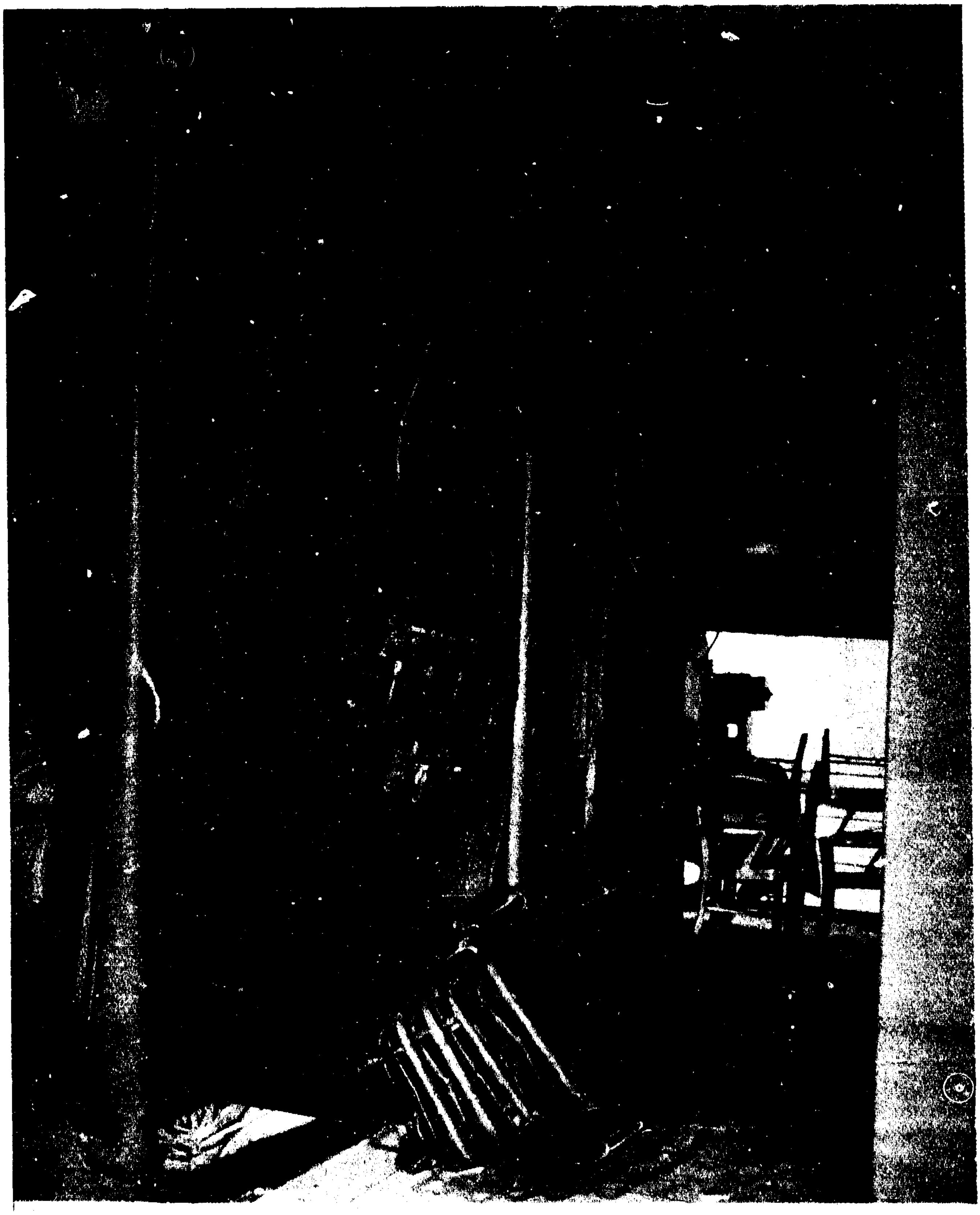
WELDING



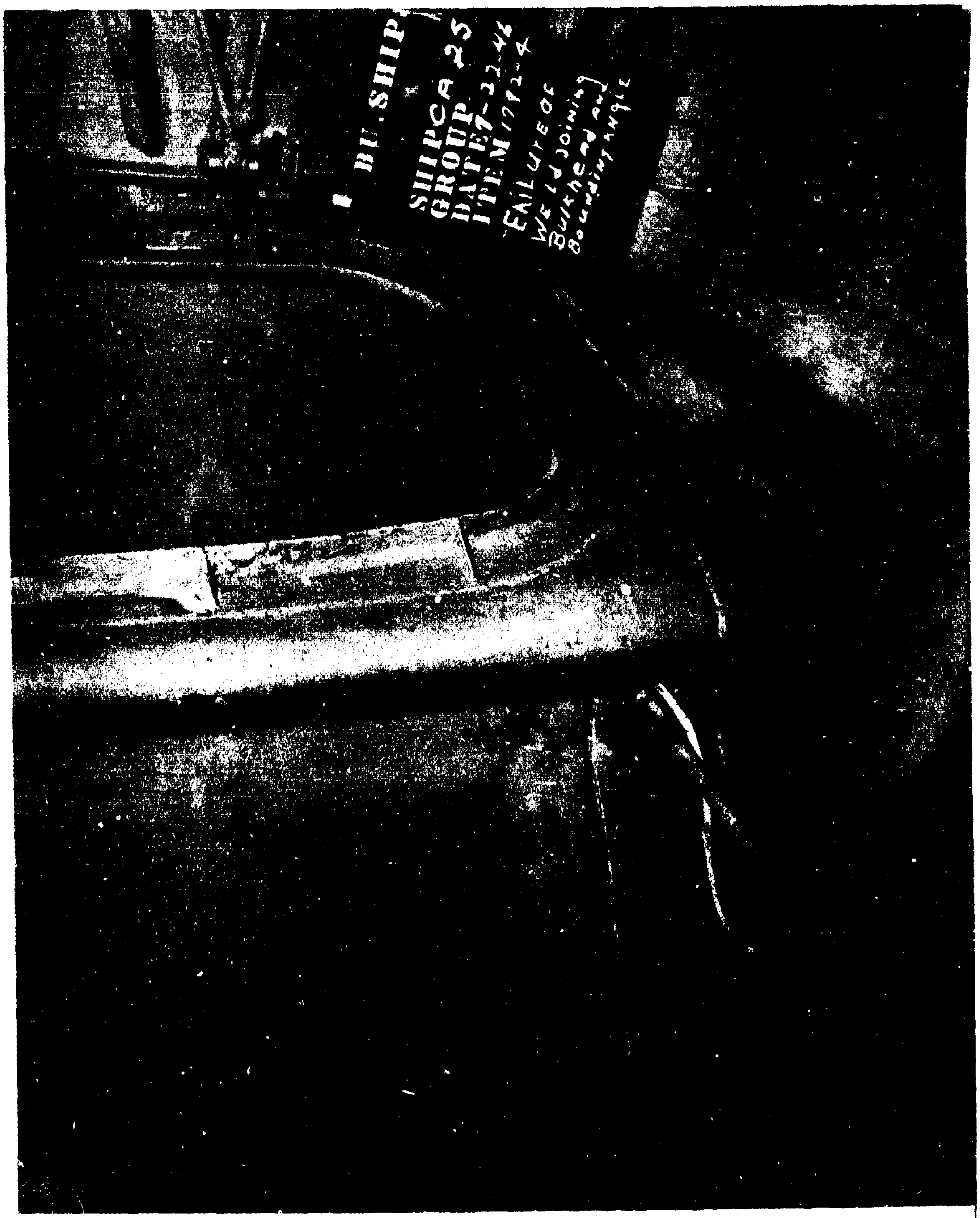
AA-CR-62-1867-2. USS SALT LAKE CITY (CA25). Displaced oxygen and acetylene cylinders. Main deck starboard passage, looking aft from well deck.

AA-CR-62-1868-3. USS SALT LAKE CITY (CA25). Displaced gas cylinders. Main deck, port, looking forward from just aft number 3 main mount.

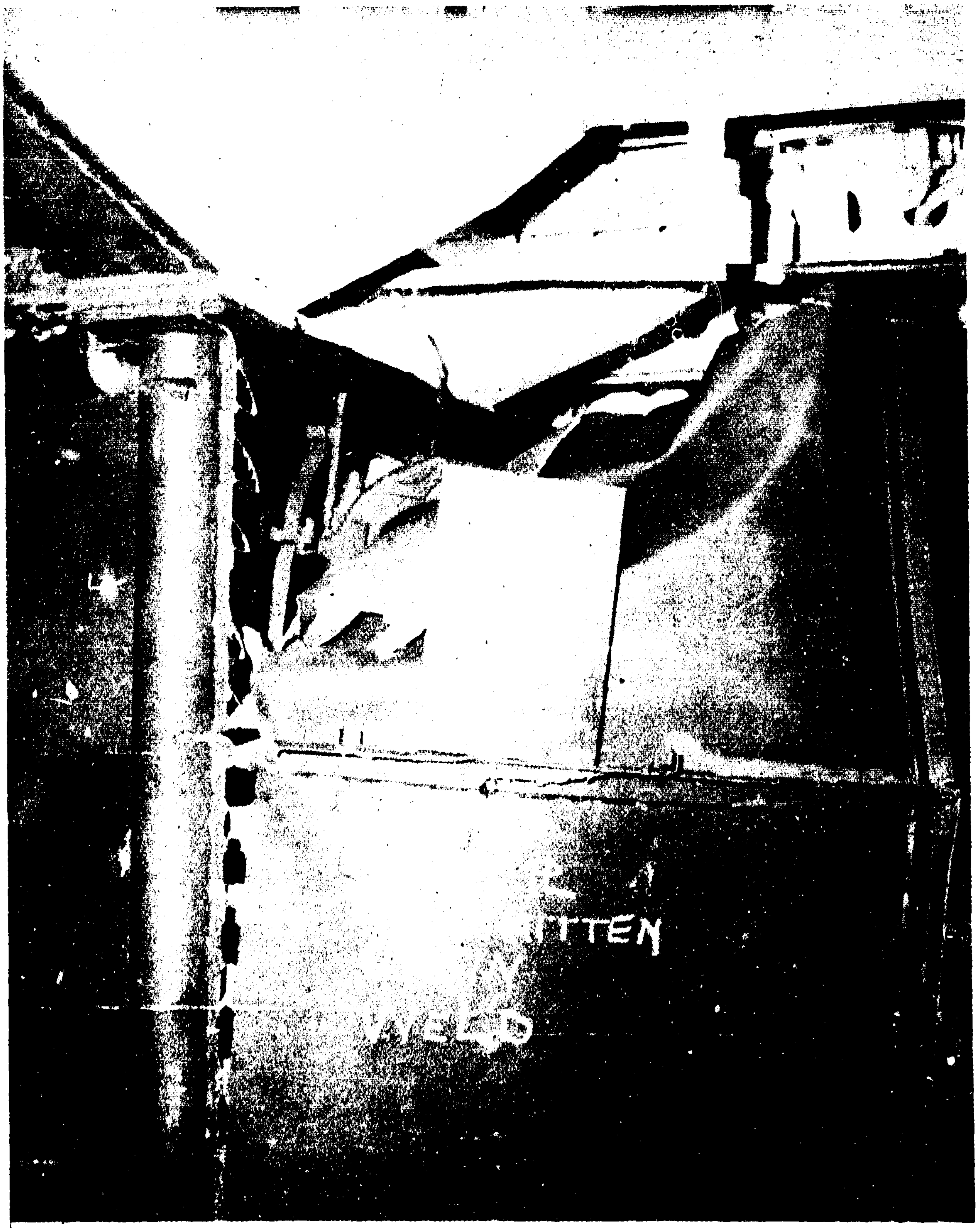
AA-CR-80-1894-5. USS SALT LAKE CITY (CA25). Damaged fibre glass insulation in forward superstructure.



AA.CR-65-1729-2. USS SALT LAKE CITY (CA25). Failure of transverse bulkhead bounding weld at deck connection. Port view through athwartship main deck passage, aft of wardroom, looking to starboard.

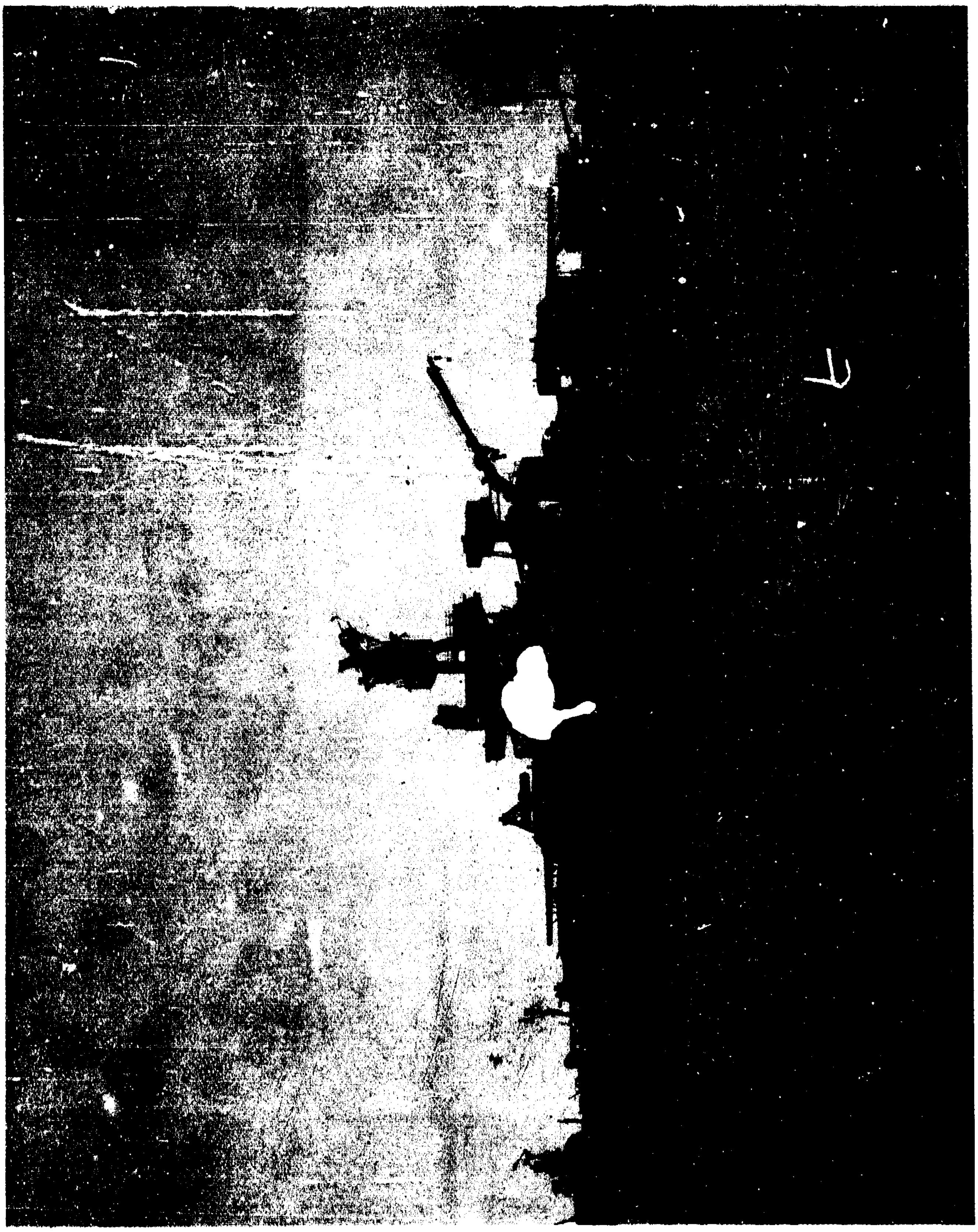


AA-CR-92-1782-4. USS SALT LAKE CITY (CA25). Failure of bulkhead bounding welds at main deck connection, port side, athwartship passage aft of wardroom, looking forward.



AA-CR-62-1868-4. USS SALT LAKE CITY (CA25). Failure in way of intermittent welds joining deck house plating to pipe stanchion at after end of port passage. Main deck, looking outboard and forward.

AA-CR-92-1782-5. USS SALT LAKE CITY (CA25). Failure in way of intermittent welds joining deck house plating to pipe stanchion at after end of port passageway. Main deck, looking outboard.



AA-CR-62-1861-1. USS ARKANSAS (BB33). Port view, showing blast damage to foremast tripod.

AA-CR-92-1783-2. USS ARKANSAS (BB33). Failure adjacent to welds in heat affected zone at cantilever bracket connection to after leg of fore-mast tripod. Looking upward.

AA-CR-92-1782-12. USS ARKANSAS (BB33). Failure adjacent to welds in heat affected zone at range finder platform cantilever bracket connection to starboard leg of foremast tripod. Looking upward. Note brittle appearance of fracture.

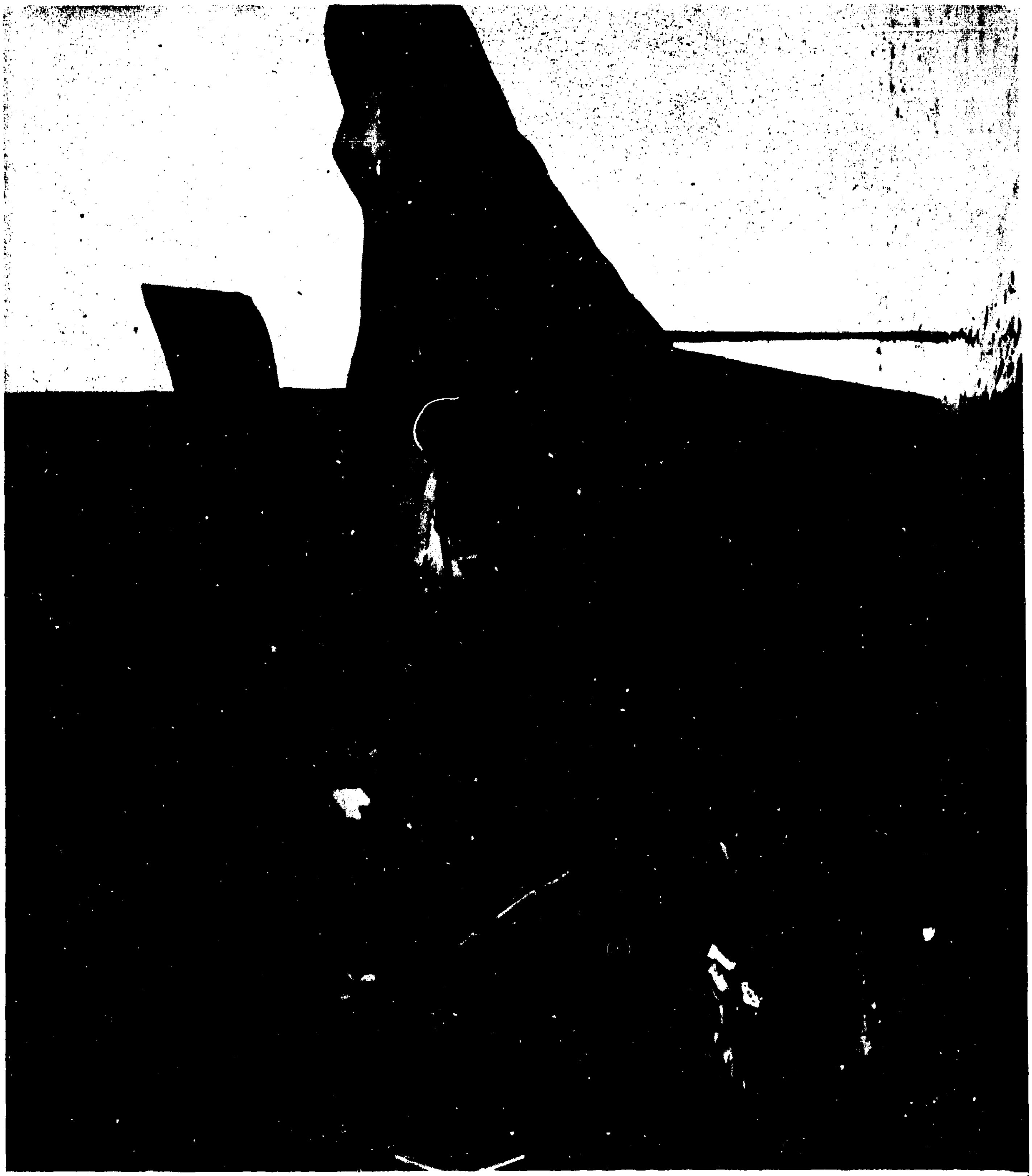
AA-CR-175-2135-3. USS ARKANSAS (BB33). Fracture of starboard foremast tripod leg in way of welded connection to cantilever support for range finder platform. Looking upward and outboard.

AA-CR-92-1782-11. USS ARKANSAS (BB33). Transverse failure of starboard leg of foremast tripod. Note origin of fracture in weld joining flange of cantilever bracket to tripod leg.

AA-CR-68-2094-8. USS ARKANSAS (BB33). Failure in starboard tripod leg of foremast, looking inboard.

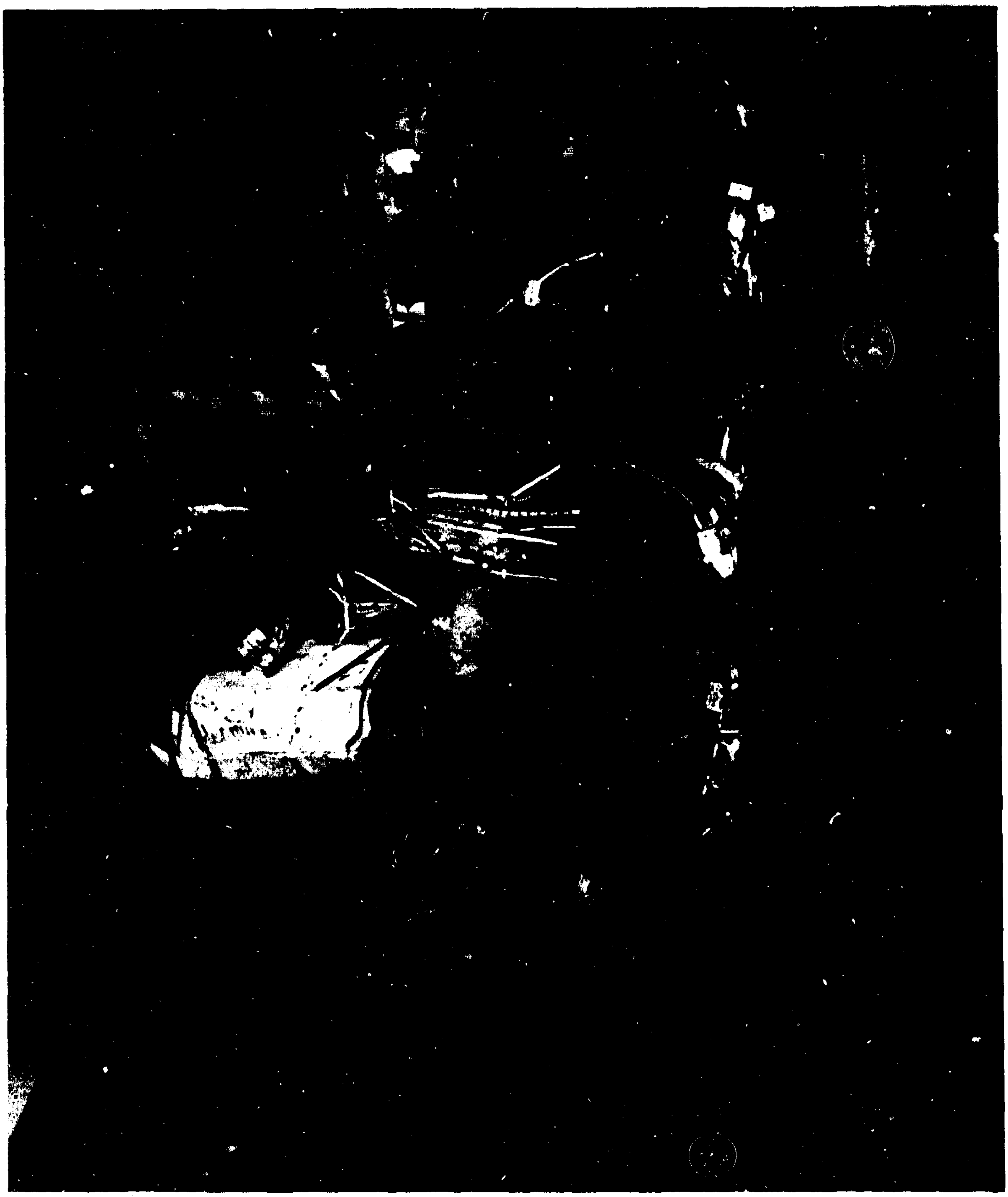
AA-CR-59-2216-2. USS INDEPENDENCE (CVL22). View of port quarter — showing blast damage to shell and superstructure. Note failures along welded seams in shell and superstructure plating.

AA-CR-59-2216-7. USS INDEPENDENCE (CVL22). Close-up view of damage to shell and superstructure, port quarter, looking upward.

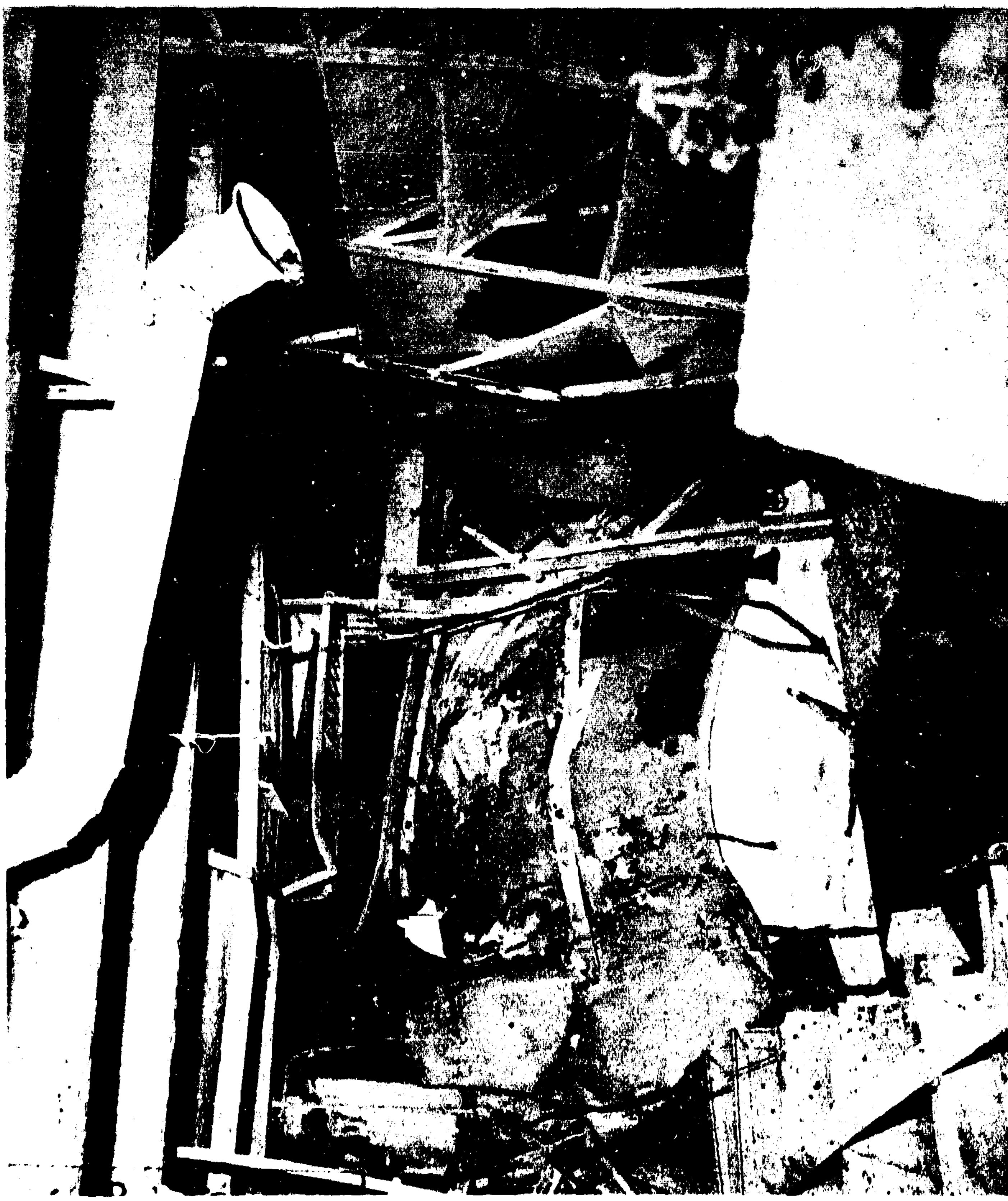


AA-CR-65-1733-11. USS INDEPENDENCE (CVL22). Port close-up view of stern showing downward deflection of main deck, ruptures in port shell, and failures in welded seams on after antiaircraft gun sponson.

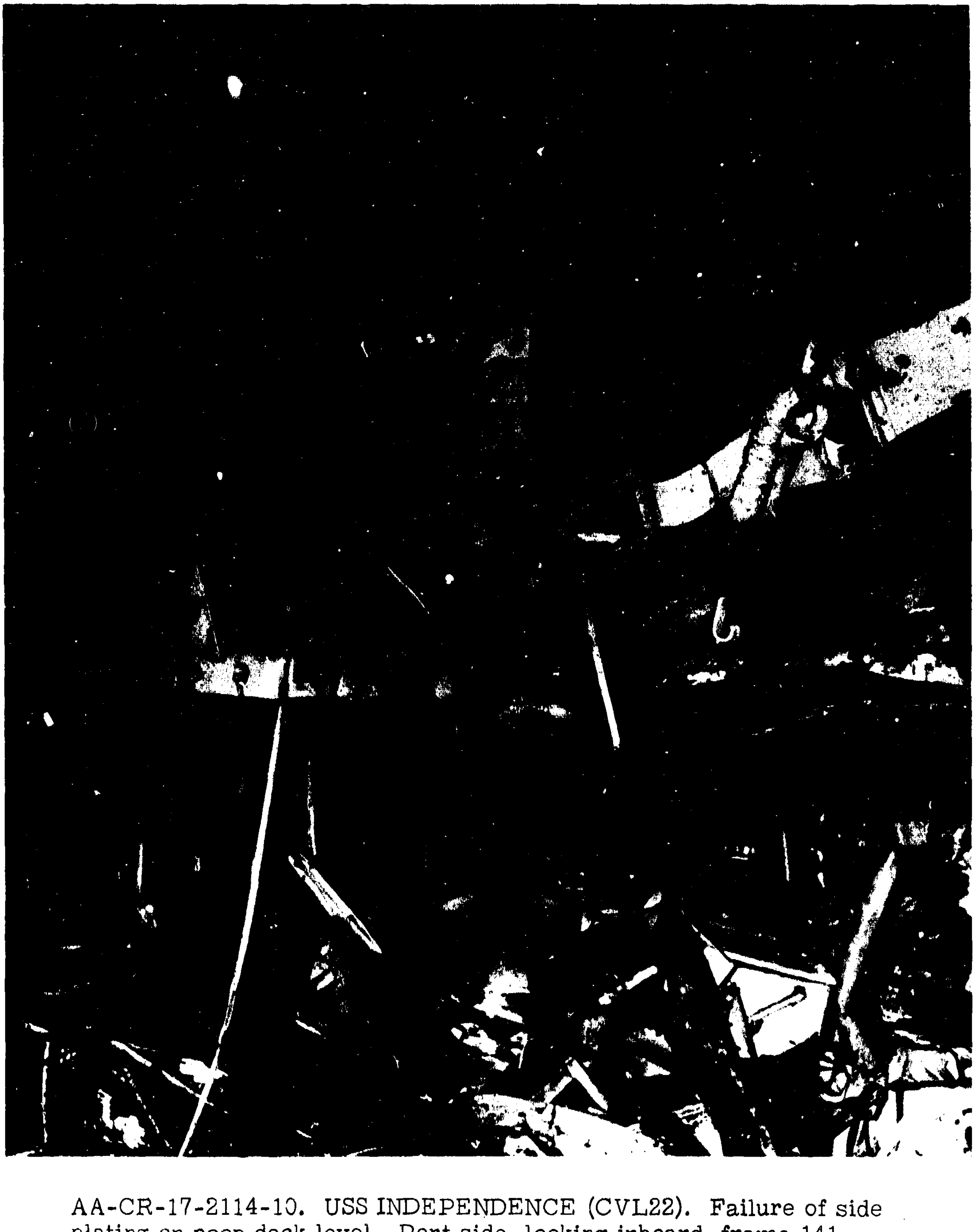
AA-CR-59-2216-11. USS INDEPENDENCE (CVL22). Stern view, port side, showing deflection of outboard edge of main deck, upward tilt of third deck above bilge and failure in shell plating.



AA-CR-65-1734-1. USS INDEPENDENCE (CVL22). Close-up view of major damage area where blast penetrated port side of ship.

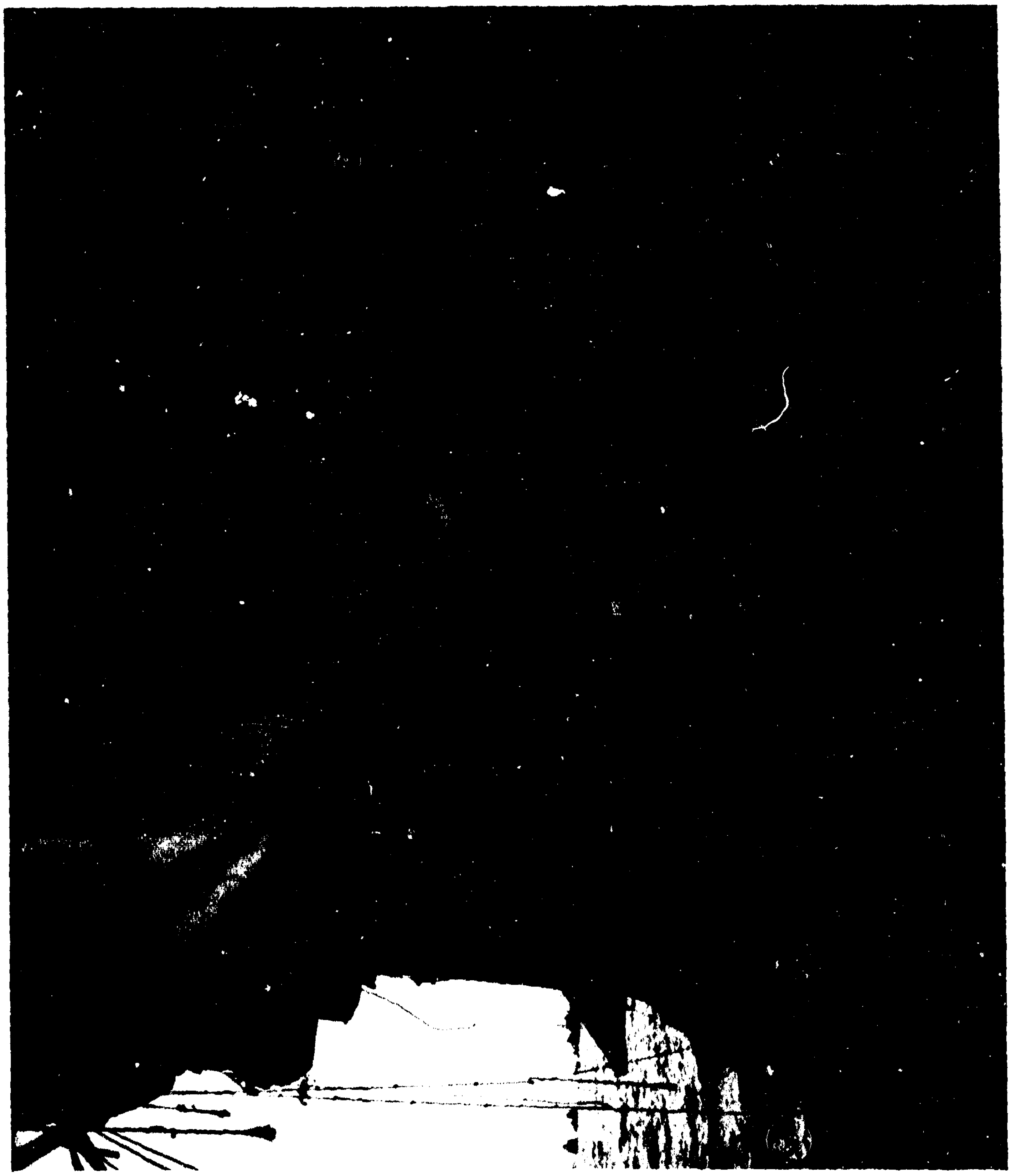


AA-CR-17-2114-1. USS INDEPENDENCE (CVL22). Failure of side plating along welded seam at level of poop deck. Port side looking outboard.



AA-CR-17-2114-10. USS INDEPENDENCE (CVL22). Failure of side plating on poop deck level. Port side, looking inboard, frame 141.

AA-CR-59-2216-5. USS INDEPENDENCE (CVL22). Damage to boat handling structure, gallery walkways and director sponson on port side in way of the hangar space after bulkhead.

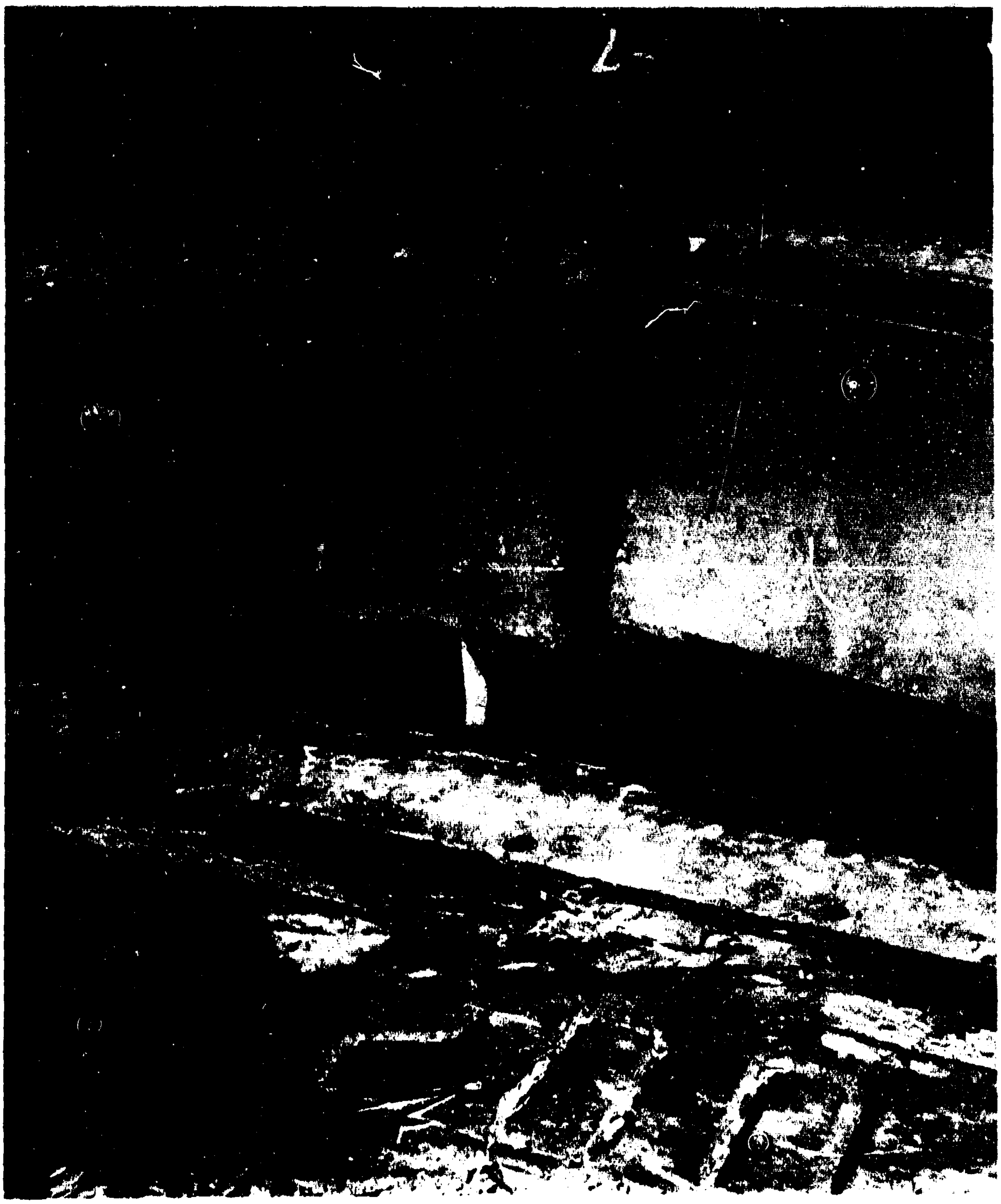


AA-CR-175-2117-10. USS INDEPENDENCE (CVL22). Outboard view of port side rupture in shell along weld connecting main deck to sheer strake. Note after face of transverse bulkhead 138, buckled by the inward displacement of the shell.

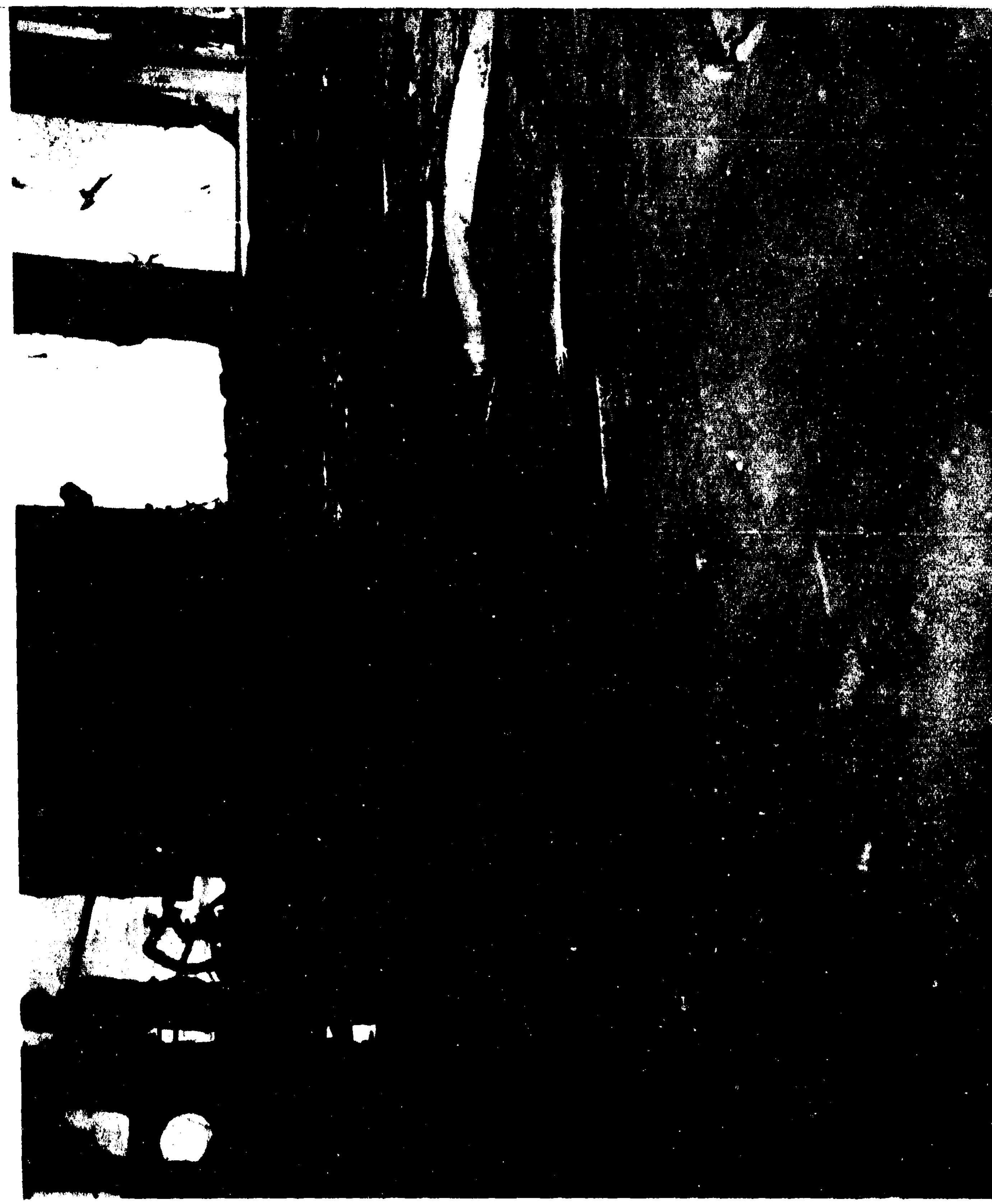
AA-CR-175-2117-11. USS INDEPENDENCE (CVL22). Outboard view along port shell, showing downward deflection of outboard edge of main deck, tears in welded seams in shell plating and distorted transverse bulkhead 147.

AA-CR-88-2'00-8. USS INDEPENDENCE (CVL22). Door in port shell in way of light lock aft of bulkhead 40 on the gallery deck. Note blast damage to fibre glass insulation, and failure of weld joining partial bulkhead to deck.

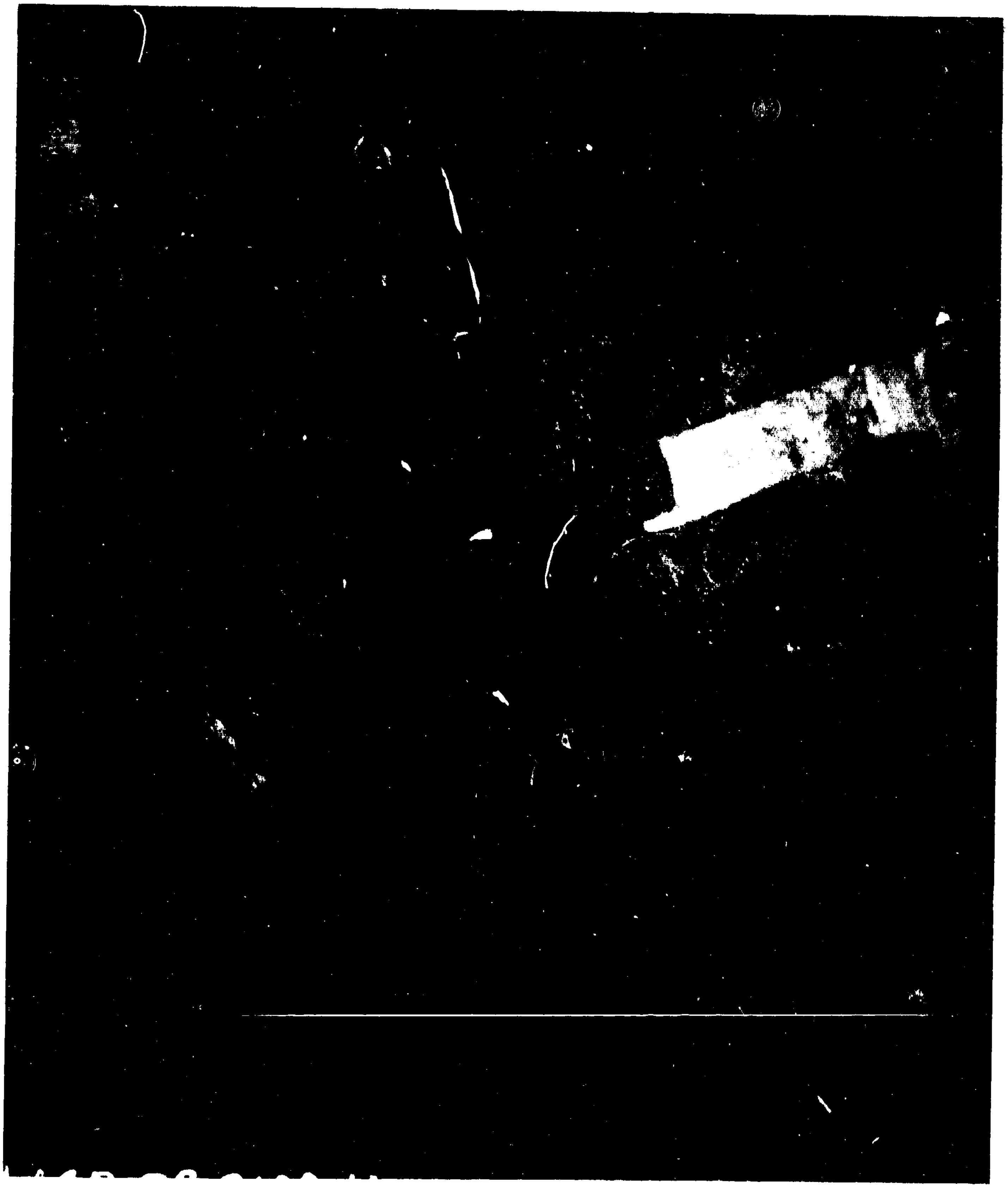
AA-CR-175-2040-10. USS INDEPENDENCE (CVL22). Fracture in welded butt in transverse deck boundary channel at expansion joint in flight deck. Frame 63 1/2, centerline, looking aft.



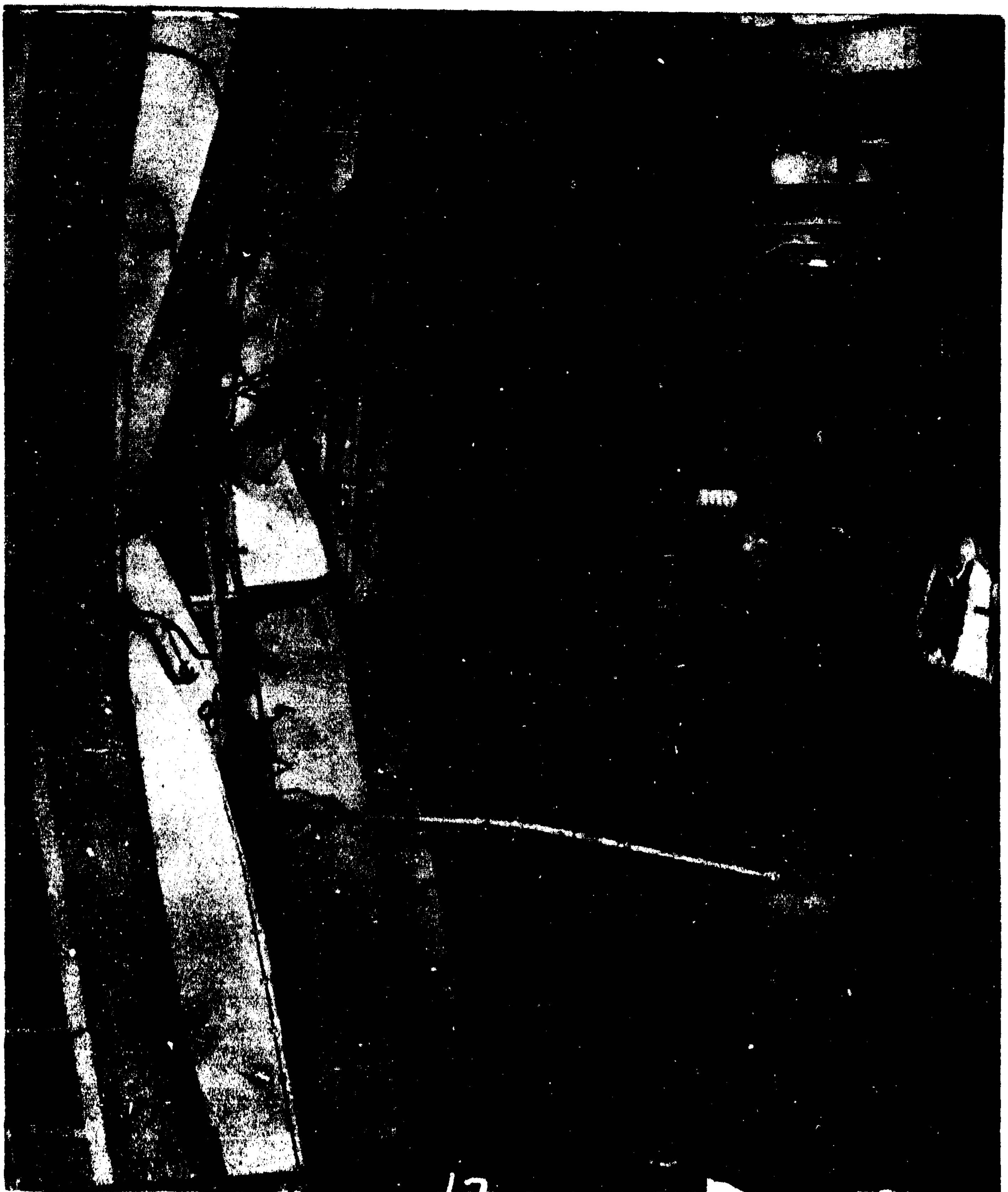
AA-CR-59-2164-7. USS INDEPENDENCE (CVL22). Fracture in welded butt in transverse deck boundary channel at expansion joint in flight deck. Frame 63 1/2, centerline, looking aft.



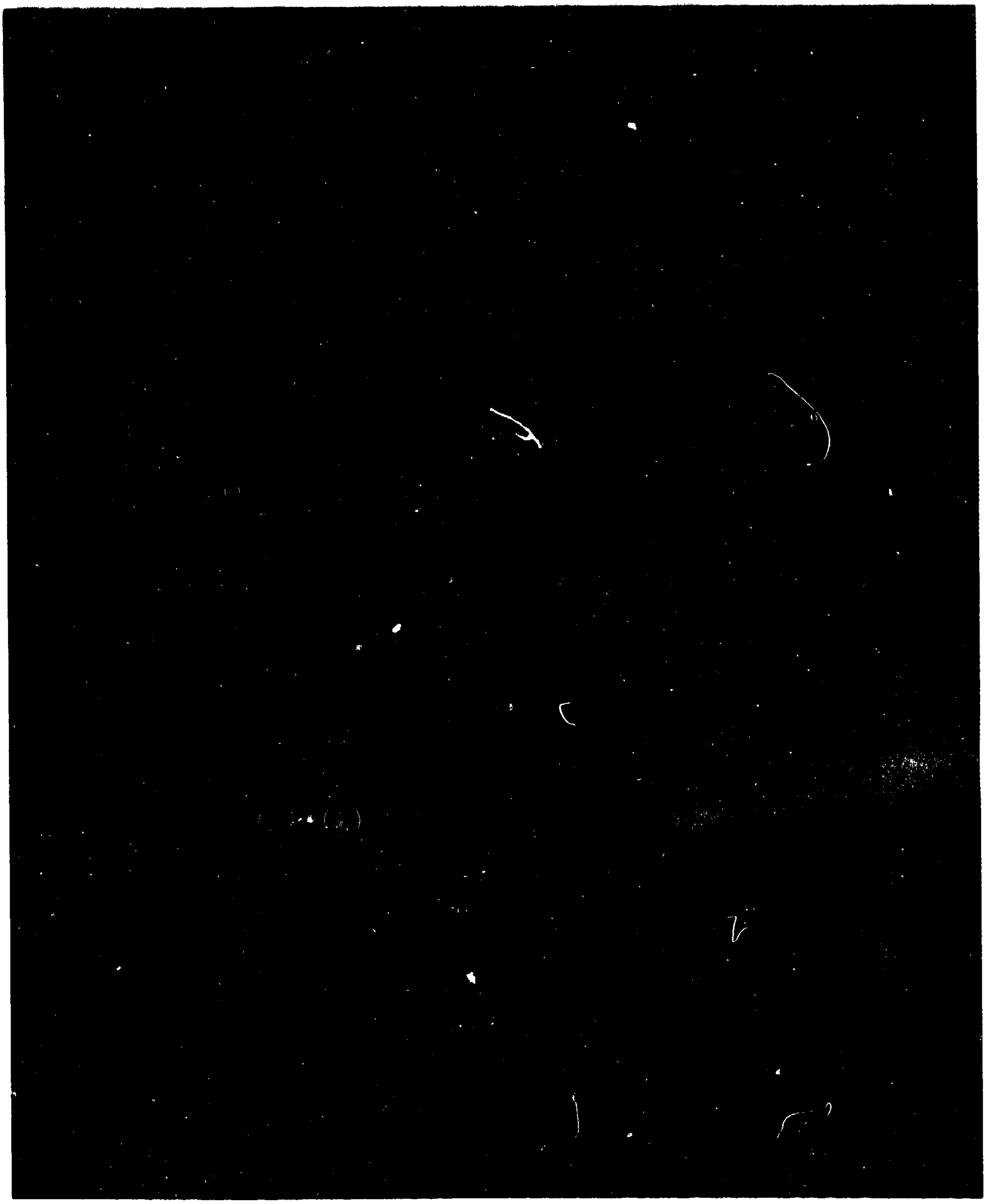
AA-CR-175-2040-2. USS INDEPENDENCE (CVL22). Deflections in 3/8 inch welded hangar deck. Looking to starboard. There were no significant failures in welds in this deck.



AA-CR-88-2100-4. USS INDEPENDENCE (CVL22). Transverse fracture in welded butt in 1/2 inch main deck plating in way of forward elevator pit. No edge preparation at joint in flush patch in deck.

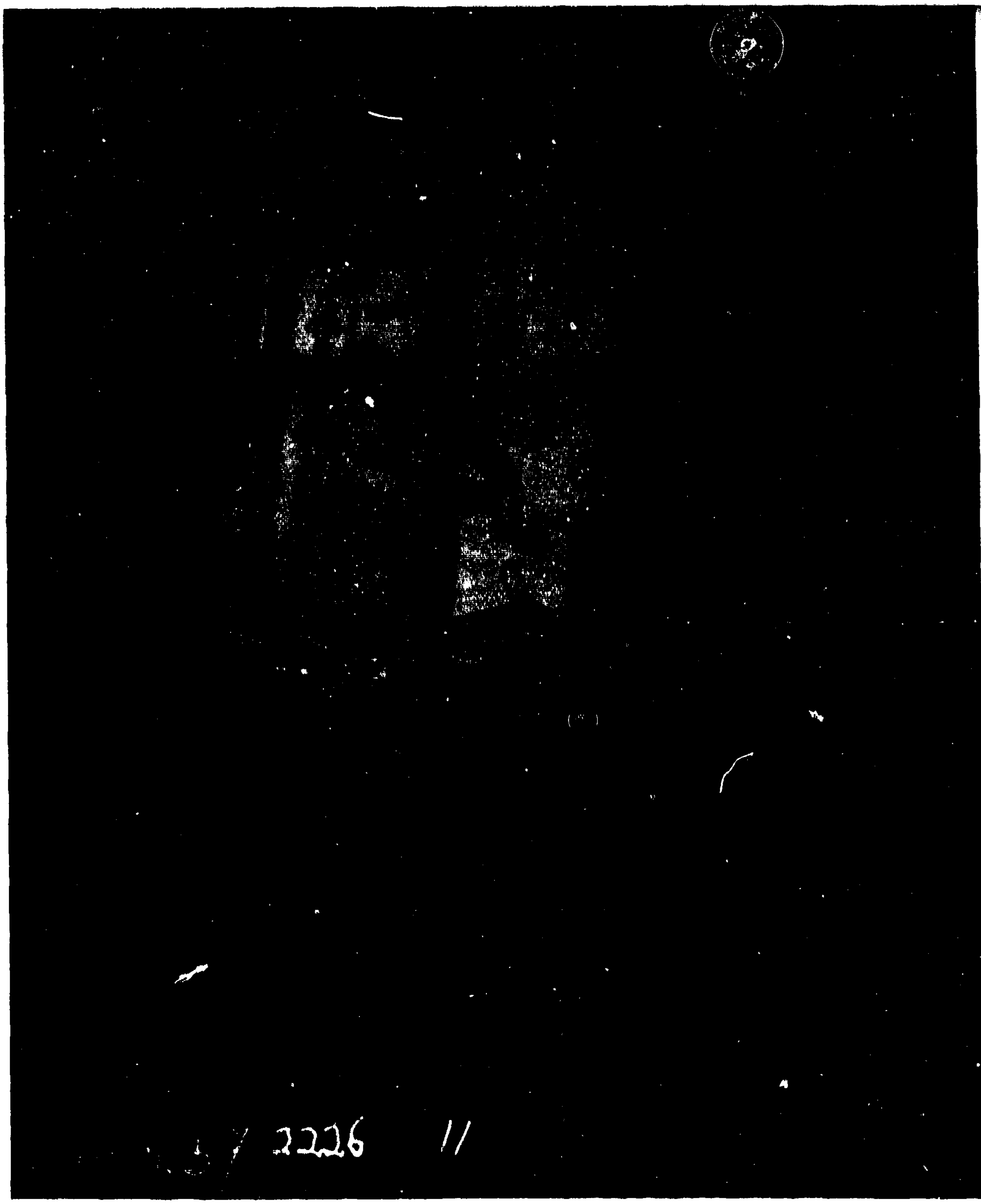


AA-CR-59-2226-12. USS INDEPENDENCE (CVL22). General view of hangar showing distortion of flight deck bent girders at centerline, and deflection of hangar deck. Looking aft.



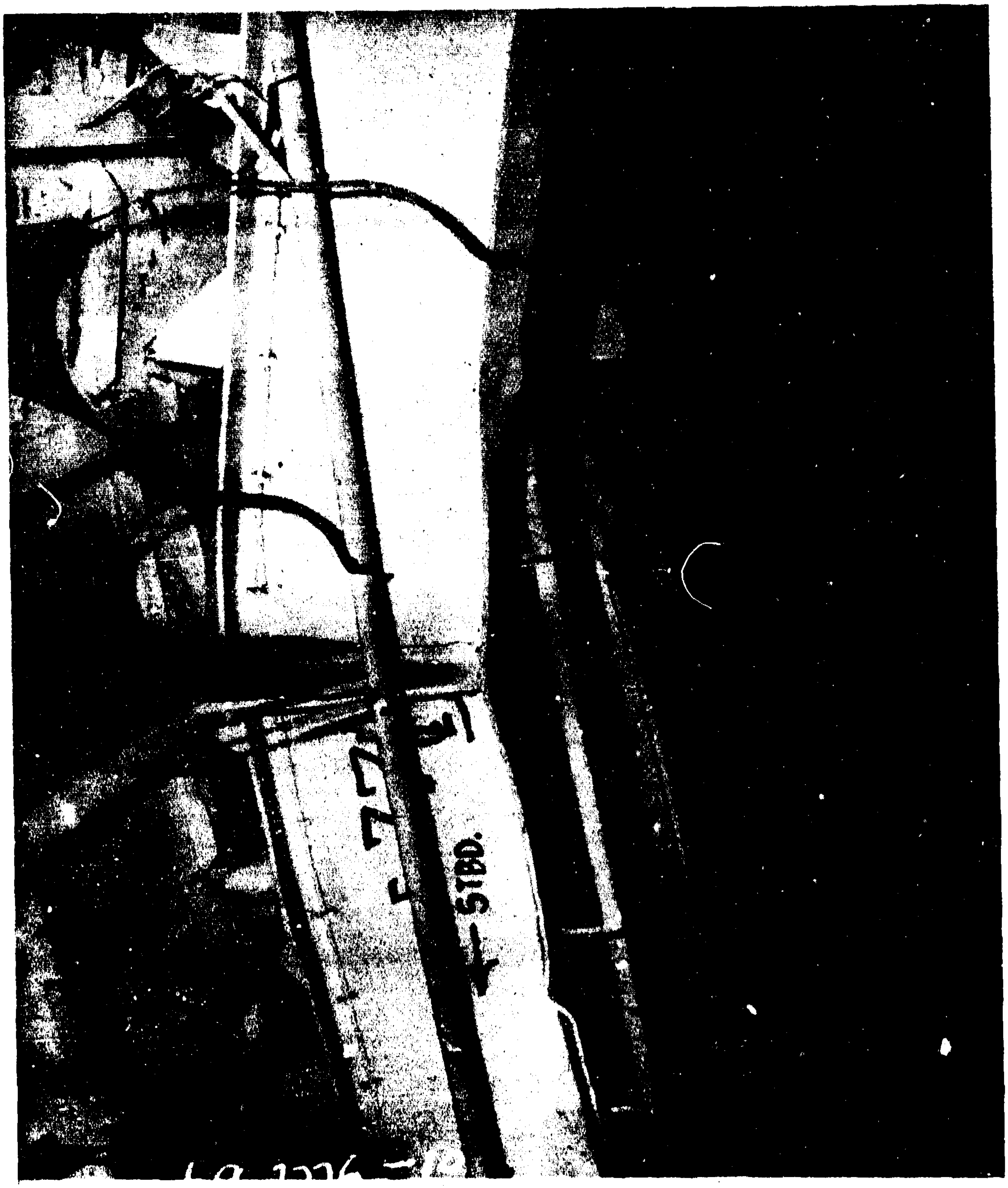
AA-CR-59-2222-12. USS INDEPENDENCE (CVL22). Fracture in flight deck bent column at port overhead bracket. Origin of fracture is at toe of fillet weld joining flange of bracket to column, looking aft.

AA-CR-59-4149-5. USS INDEPENDENCE (CVL22). Fracture in flight deck bent column at port overhead bracket. Note herring bone pattern of fracture pointing to origin at toe of fillet weld at left.



AA-CR-59-2226-11. USS INDEPENDENCE (CVL22). Fracture in centerline butt weld in flight deck bent girder. Fracture originated in weld in lower flange. Looking forward.

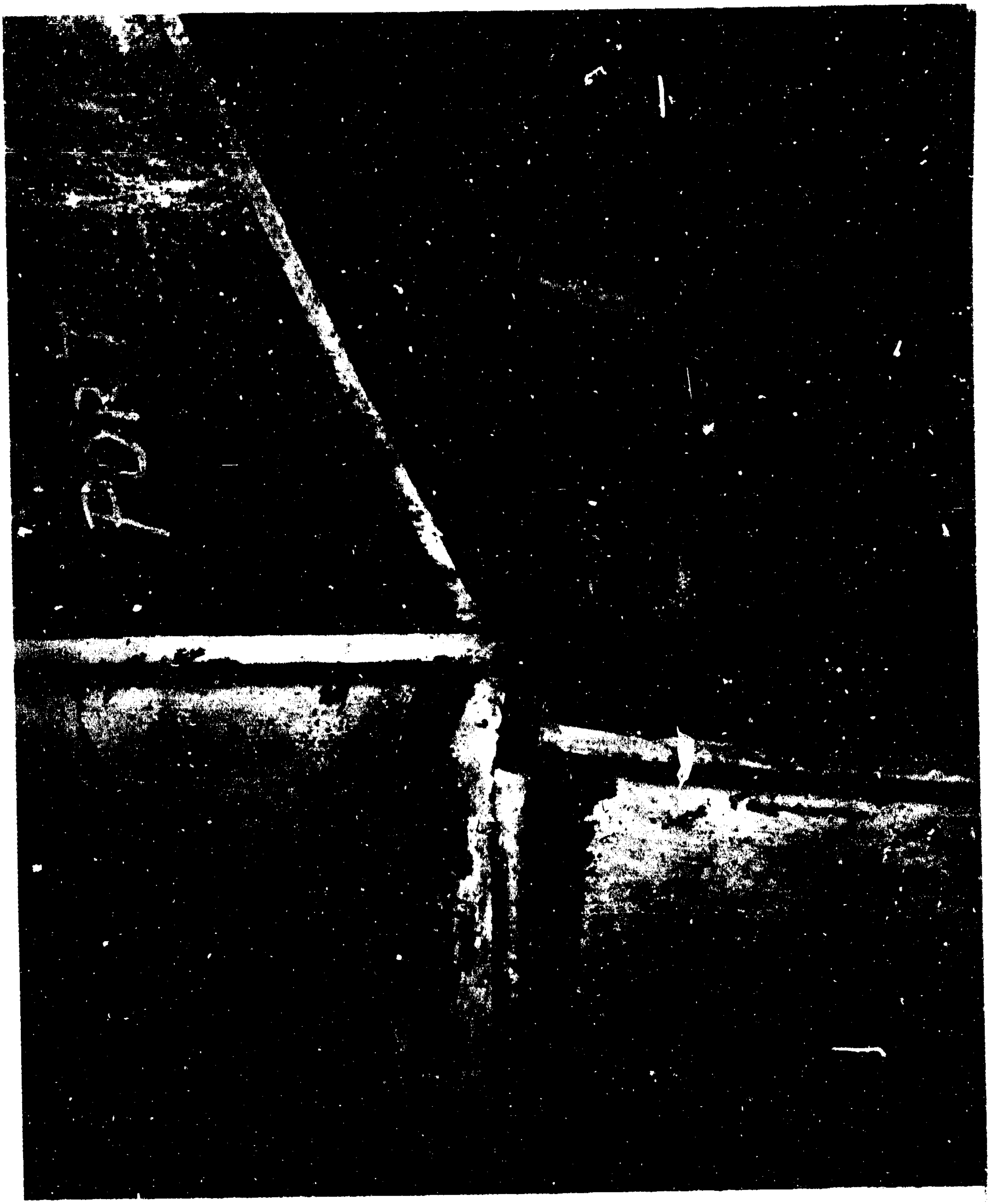
AA-CR-59-4148-11. USS INDEPENDENCE (CVL22). Fracture in flight deck bent overhead connection along inboard edge cf vertical weld. Frame 74, looking forward.



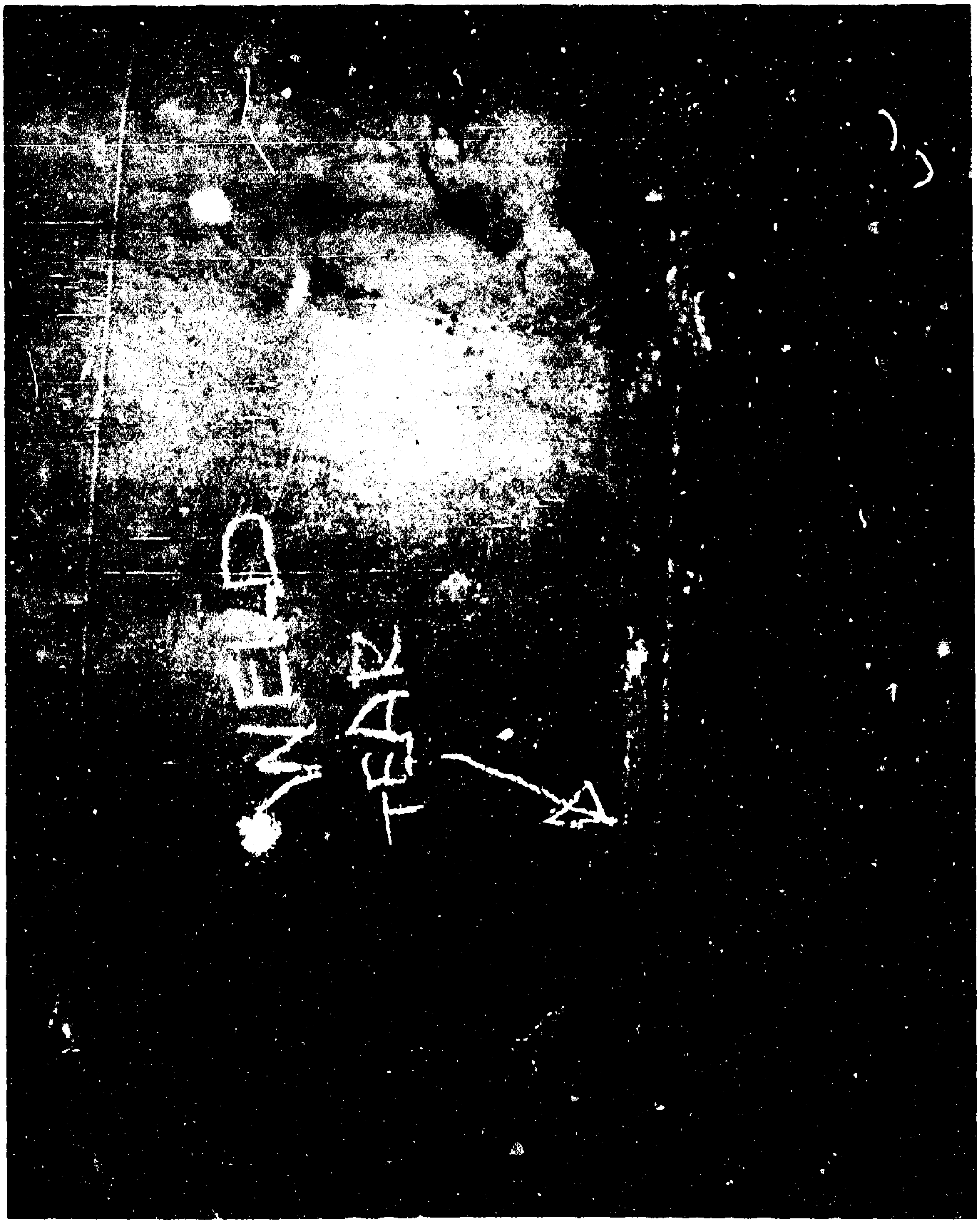
AA-CR-59-2226-10. USS INDEPENDENCE (CVL22). Fracture in center-line butt weld in flight deck bent girder. Fracture originated in weld in upper flange. Looking aft.

AA-CR-59-2226-1. USS INDEPENDENCE (CVL22). Failure of welds joining flight deck bent girder and bracket to column. Starboard side, frame 83, looking outboard.

AA-CR-100-4160-10. USS INDEPENDENCE (CVL22). Failure of welds joining flight deck bent girder and bracket to column. Close-up view showing undersize welds and lack of edge preparation. Starboard, frame 83, looking outboard.



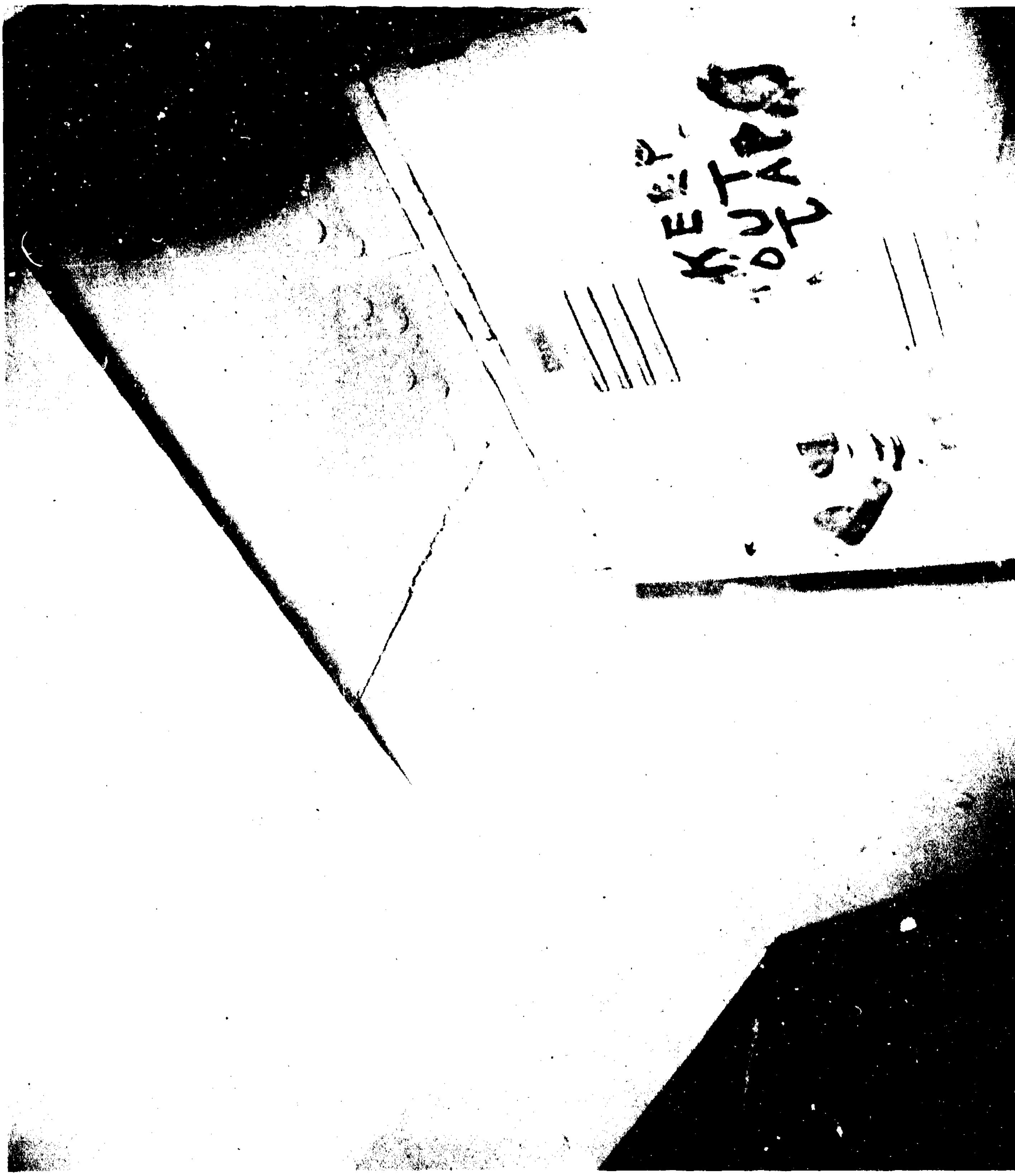
AA-CR-59-2222-11. USS INDEPENDENCE (CVL22). Failure of port overhead connection in flight deck wobble bent 65. Note origin of failure in fillet weld joining bracket flange to column.



AA-CR-100-4162-2. USS INDEPENDENCE (CVL22). Failire at edge of CRS weld joining flight deck bent column at STS sheer strake at frame 89.

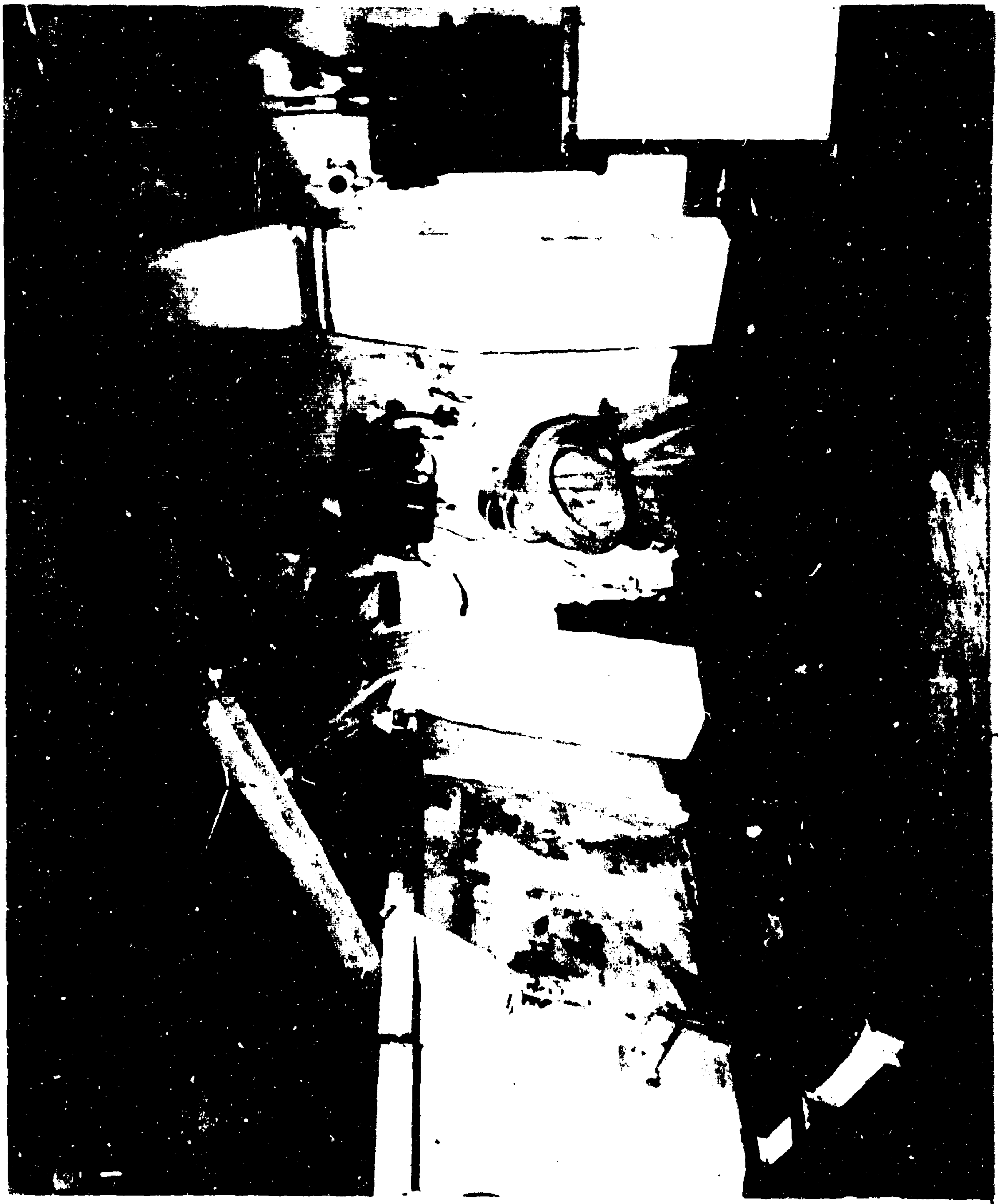
AA-CR-65-1734-8. USS INDEPENDENCE (CVL22). Port view of hangar and flight deck in way of expansion joint. Note hangar side plating has been carried away inboard and gallery walkways, gun platforms and bents are heavily damaged.

AA-CR-65-959-1. USS INDEPENDENCE (CVL22). Fracture in austenitic welds joining flight deck bent column 89 to STS sheer strake. Port side, looking aft. For outboard view see photograph 4162-2.

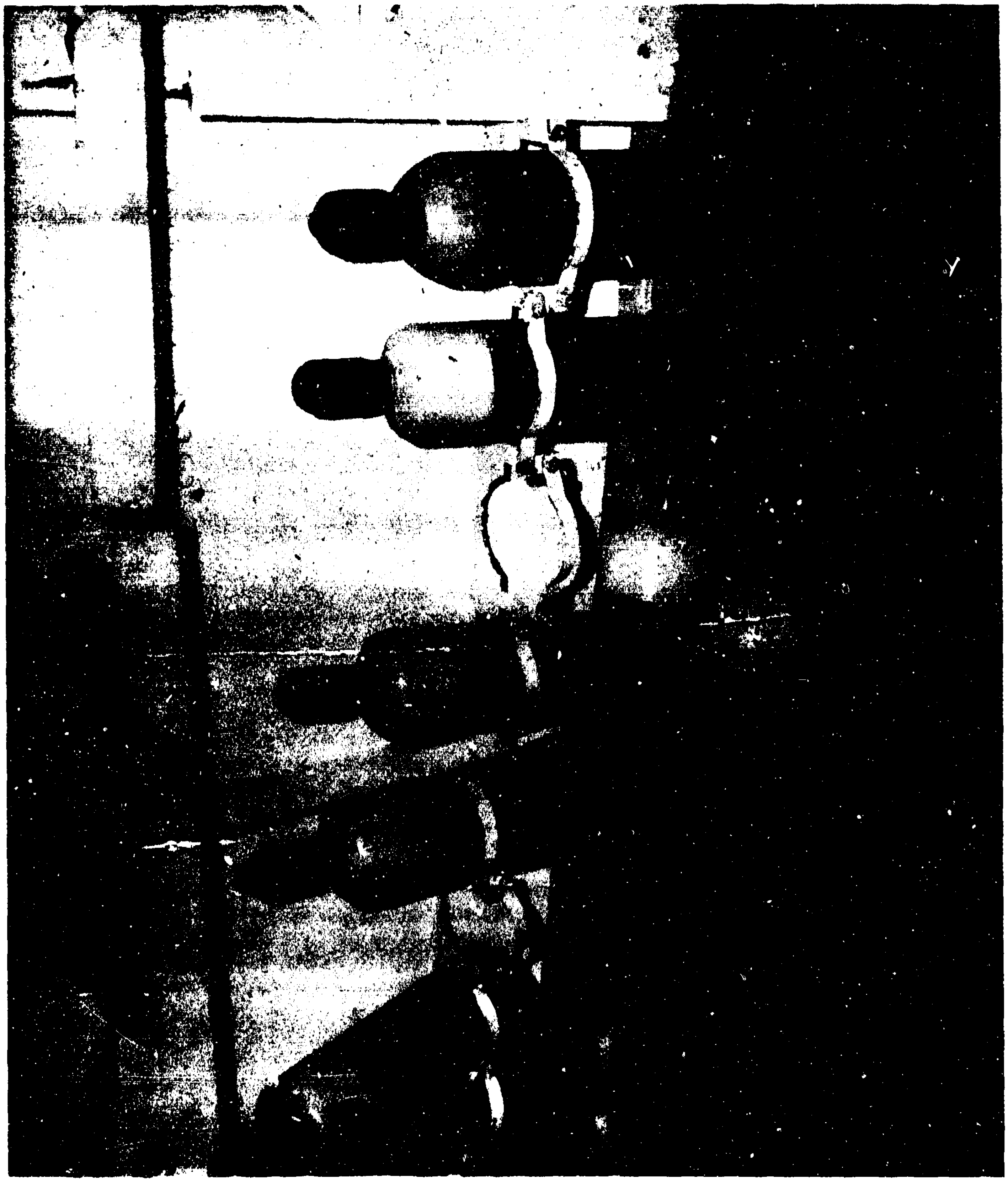


AA-CR-59-2088-7. USS INDEPENDENCE (CVL22). Fracture in web adjacent to weld joining web frame 89, port, to STS stringer strake of main deck. This failure is underneath failure at footing of flight bent 89 shown in photographs 4162-2 and 955-1.

AA-CR-59-2164-2. USS INDEPENDENCE (CVL22). Close-up view of fracture in web at welded connection of web frame 89 to STS stringer strake of main deck. See photograph 2088-7.



AA-CR-92-2071-1. USS INDEPENDENCE (CVL22). Inward deflection of port shell, second deck, aft of bulkhead 132, showing tear and wrinkle in deck, fracture in weld in mid-height shell stringer and buckled overhead main deck girders.

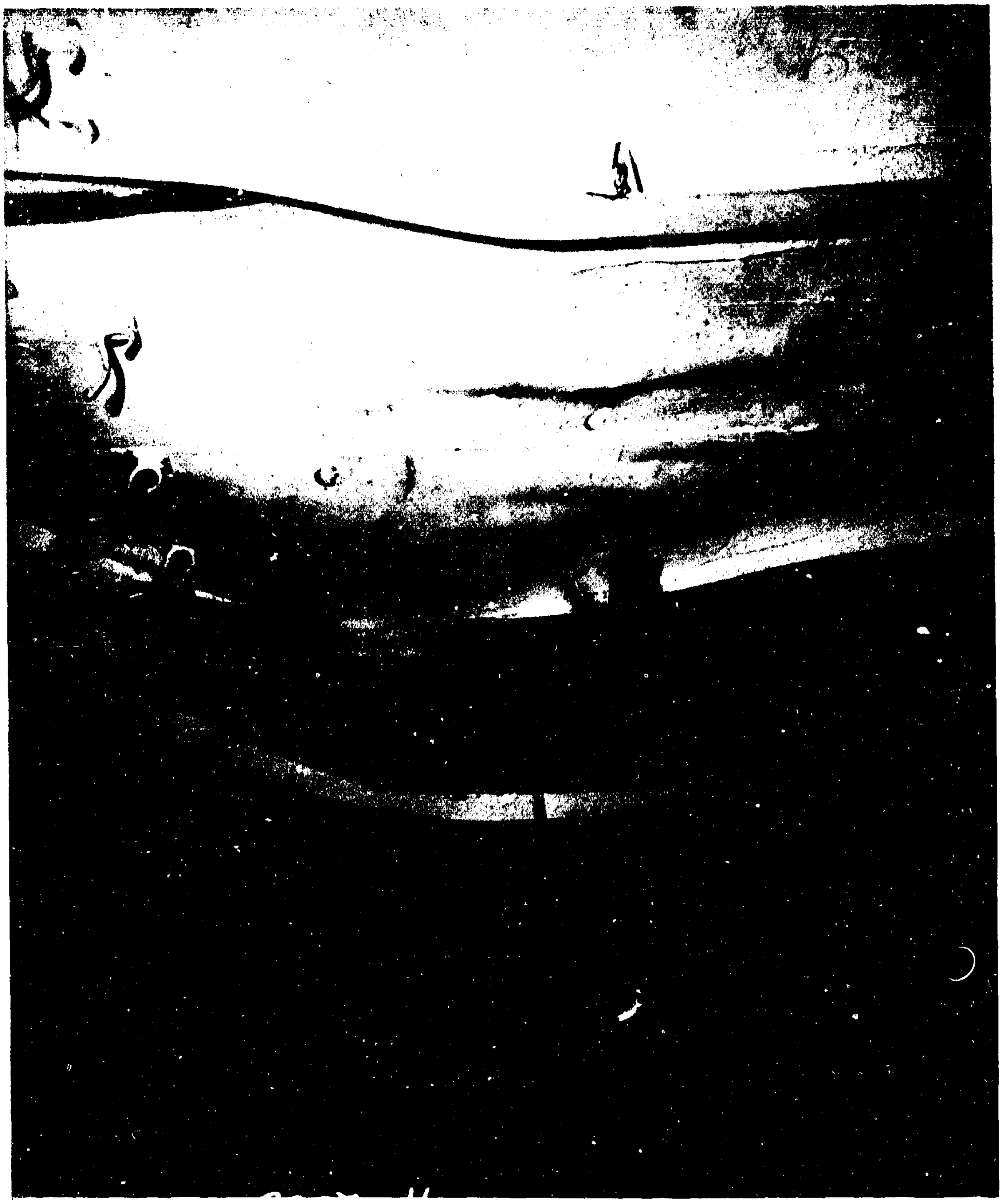


AA-CR-175-2116-12. USS INDEPENDENCE (CVL22). Weld fractures in mid-height stringer and shell frame in way of bulged port shell. Third deck frames 124 and 125. Note displaced gas bottles.

AB-CR-66-146-4. USS INDEPENDENCE (CVL22). Test A damage, showing bulged port shell, buckled web frame 110 and failure of weld connecting web to third deck.

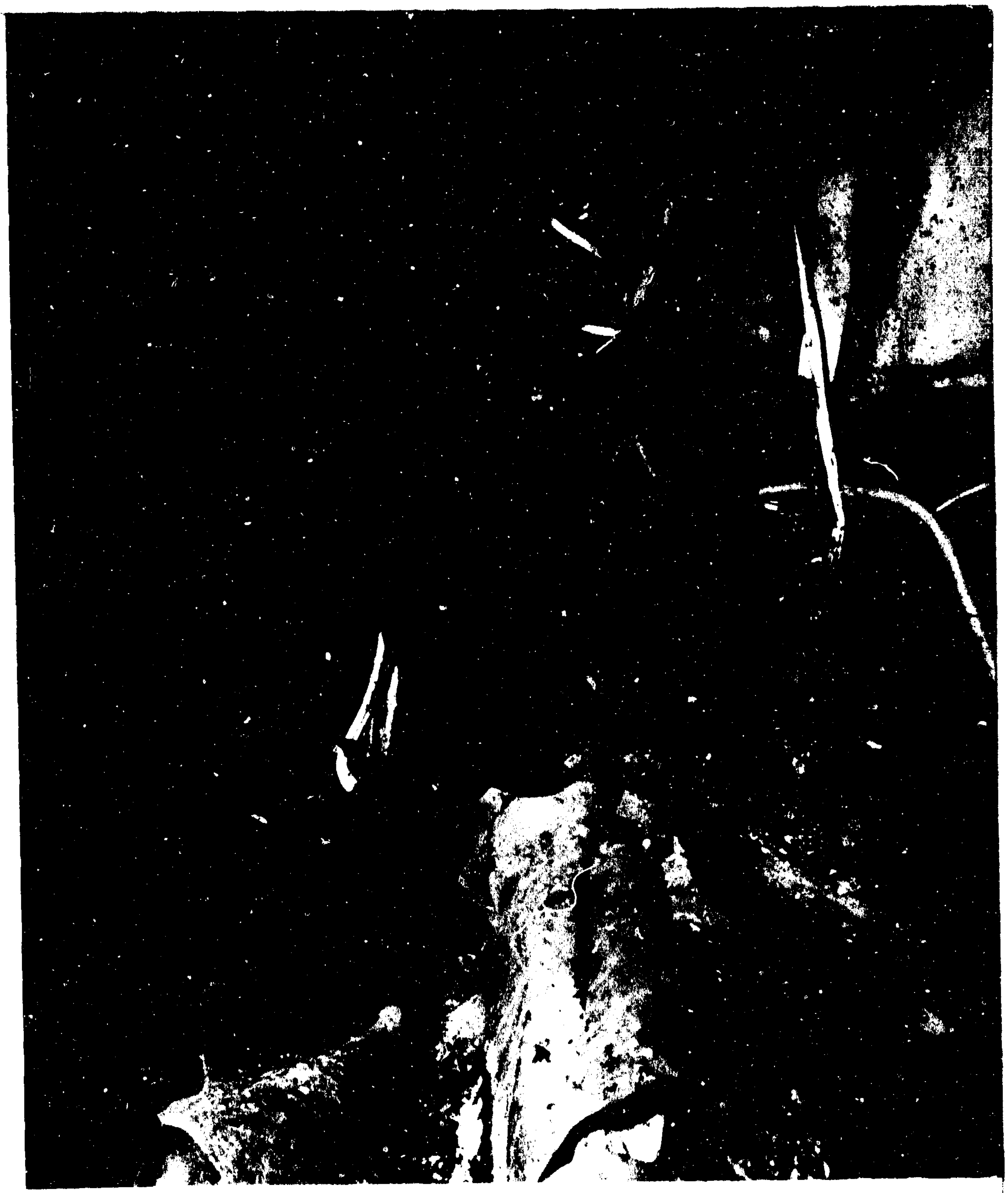
AB-CR-66-146-5. USS INDEPENDENCE (CVL22). Test A damage, showing close-up view of failure in weld connecting web to third deck.

AA-CR-175-2041-7. USS INDEPENDENCE (CVL22). Fire and blast damage in shipfitters shop on the main deck aft of the hangar space showing failure of the weld joining bulkhead 138 to the deck. See lower right hand corner of photograph.

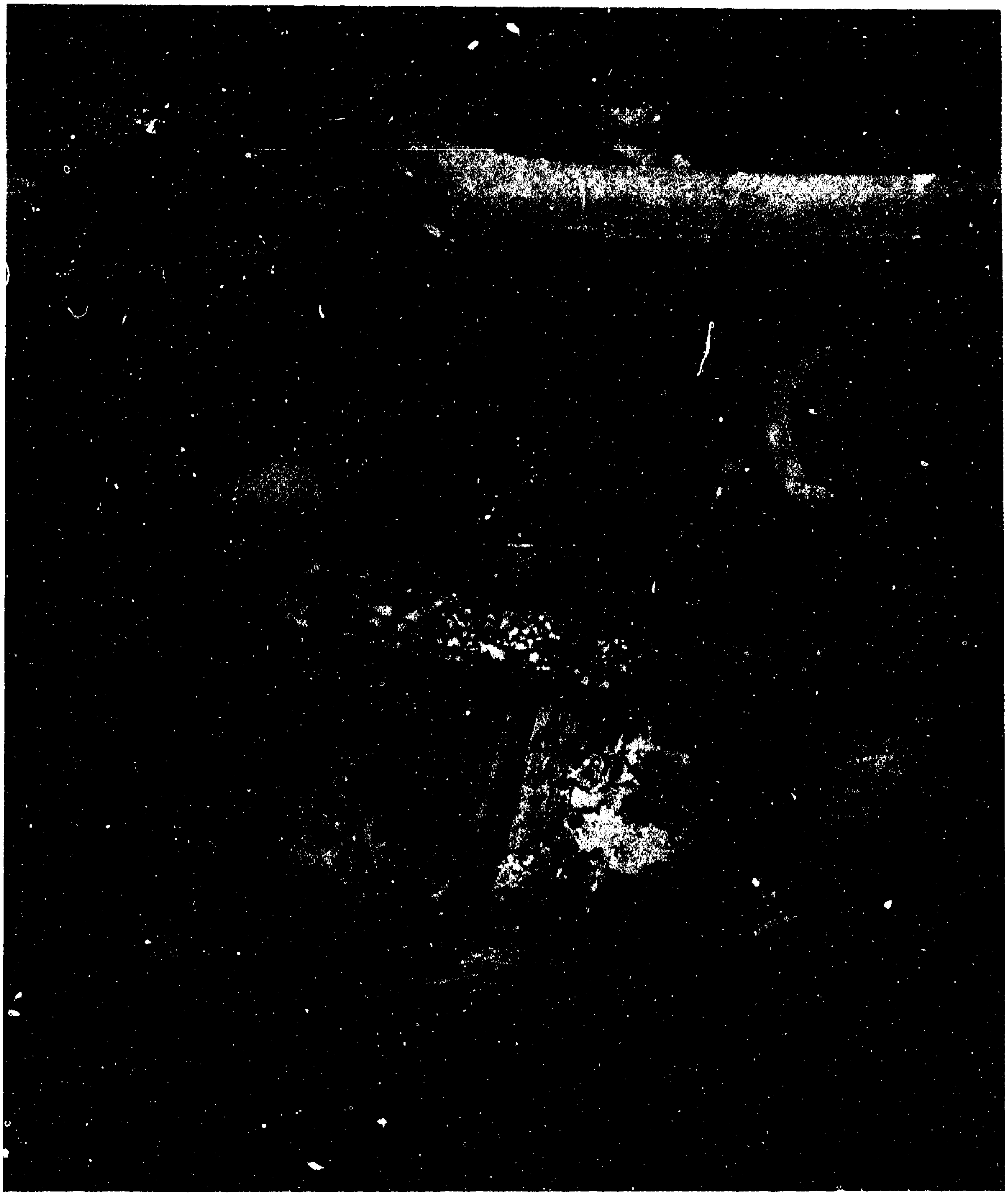


AA-CR-54-2227-11. USS INDEPENDENCE (CVL22). Bulkhead 45, gallery deck, port side, forward of the hangar space, showing deformed stiffeners and fibre glass insulation secured by end welded pins. Bulkhead is of welded construction.

AA-CR-175-2116-7. USS INDEPENDENCE (CVL22). Wrinkled in bulkhead and third deck in way of port shell deflection resulting from blast. Note performance of welded construction.

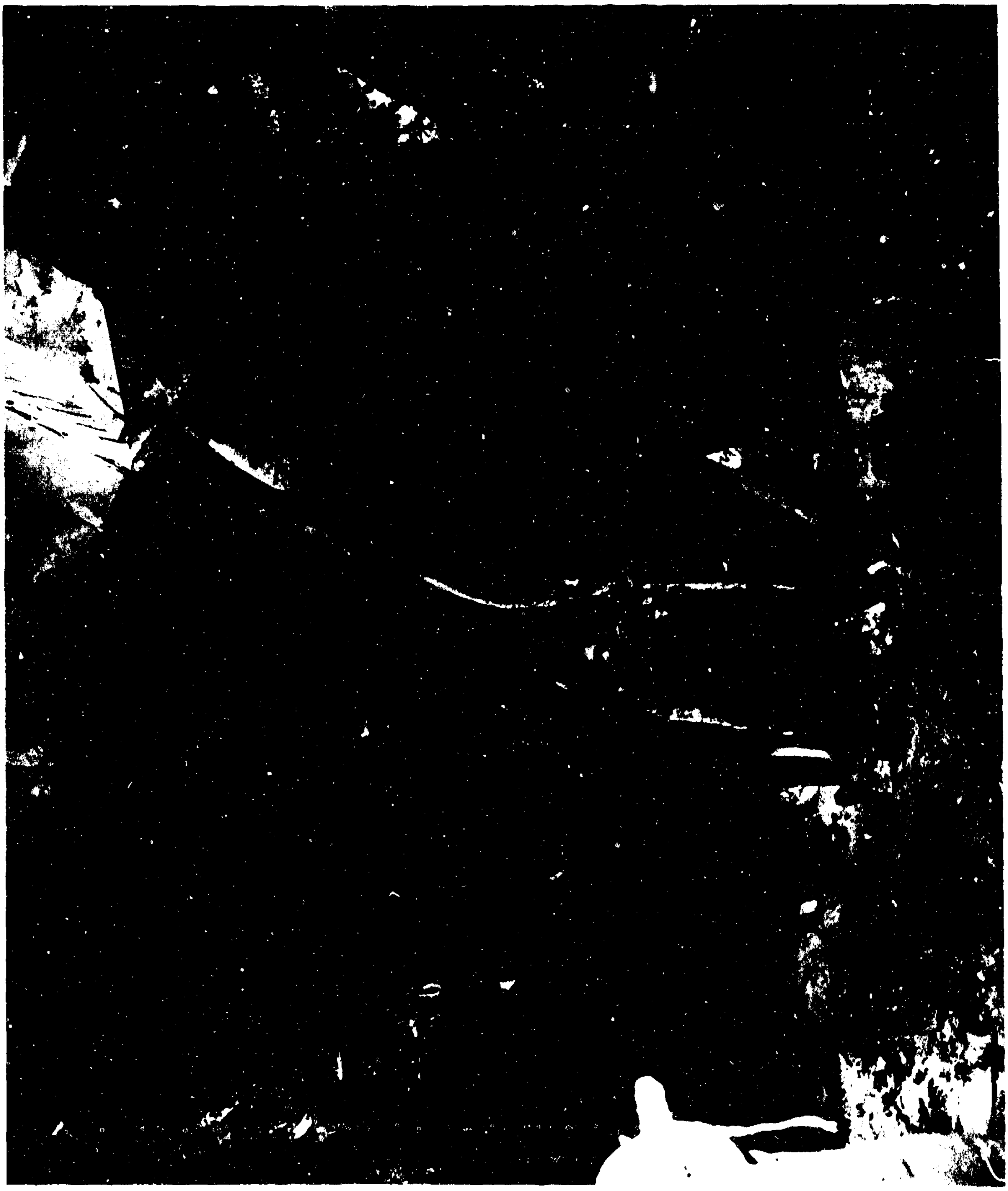


AA-CR-175-2114-11. USS INDEPENDENCE (CVL22). Failure of weld joining transverse bulkhead 138 to poop deck. Port side, looking forward.



AA-CR-59-2217-1. USS INDEPENDENCE (CVL22). Failure of welds in superstructure plating and in boat handling structure, aft of hanger space.

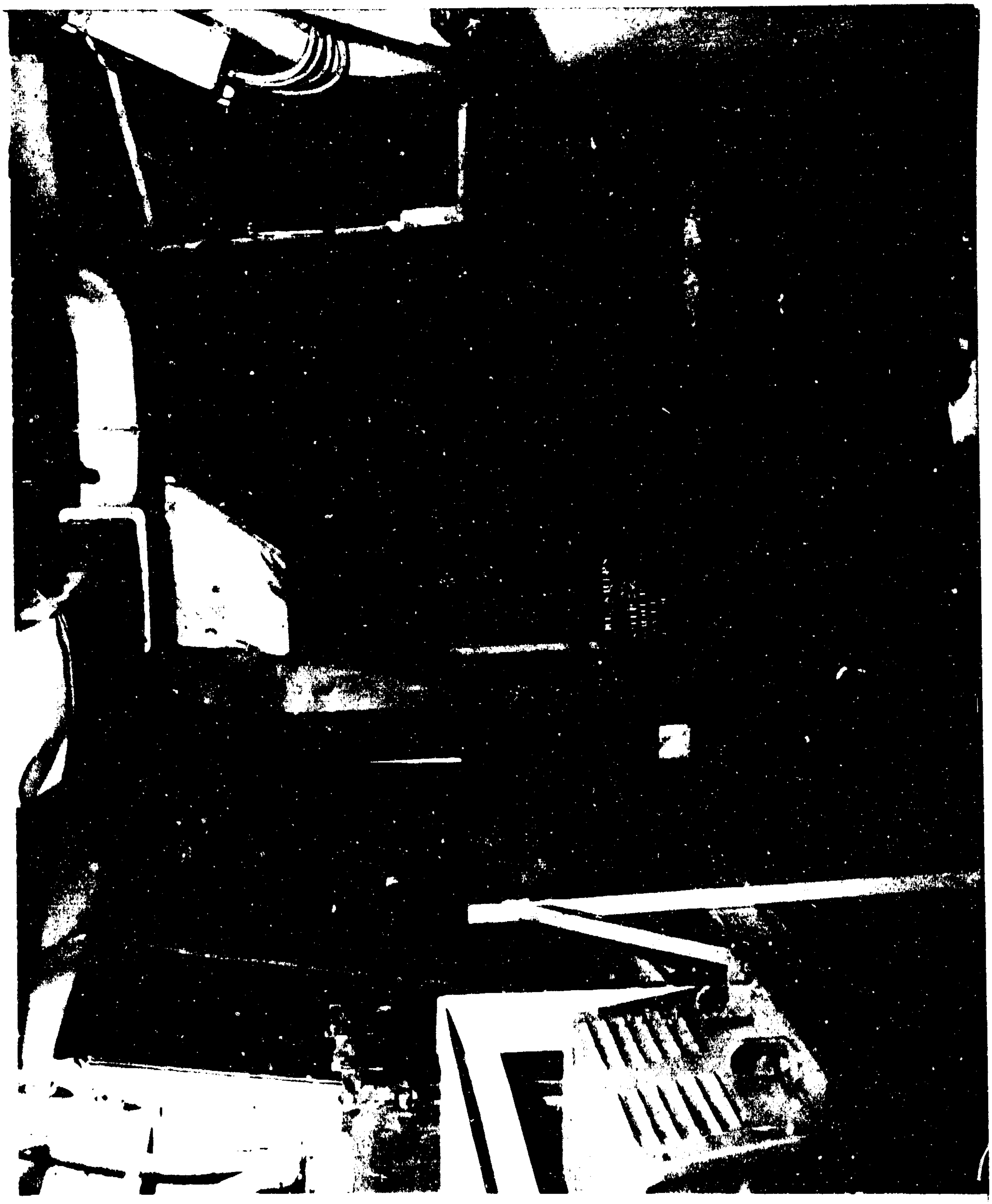
AA-CR-175-2118-2. USS INDEPENDENCE (CVL22). General view of damage to ventilation ducts, second deck port side aft of bulkhead 144.



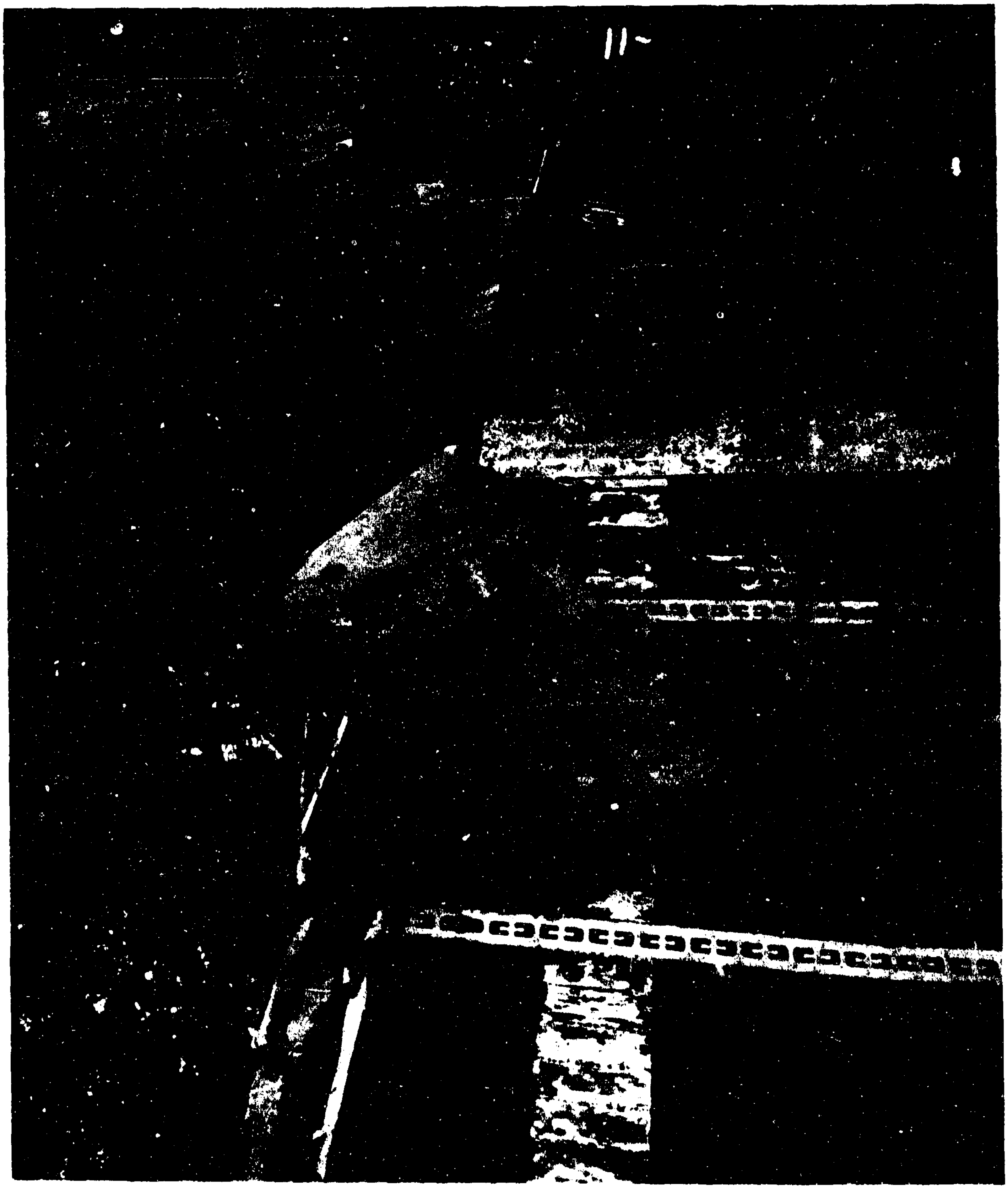
AA-CR-175-2114-6. USS INDEPENDENCE (CVL22). Damage to bolted ventilation duct. Poop deck, port side.

AA-CR-175-2133-8. USS INDEPENDENCE (CVL22). Failure of arc welded ventilation duct. Second deck, port passage, frame 63. Blast penetrated ventilation system.

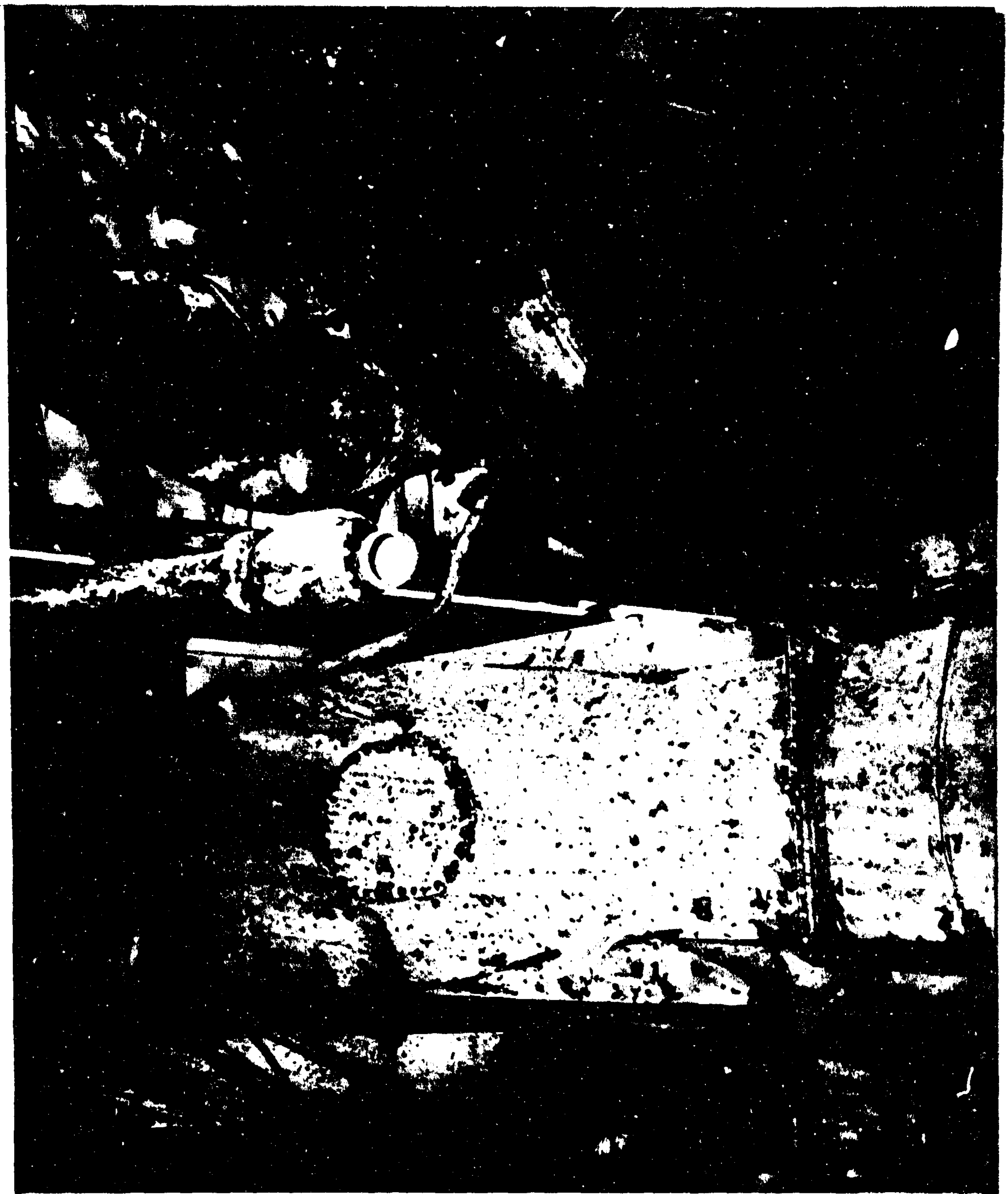
AA-CR-175-2133-10. USS INDEPENDENCE (CVL22). Failure of arc welded ventilation duct from blast which penetrated system. Second deck, port, looking forward at frame 83.



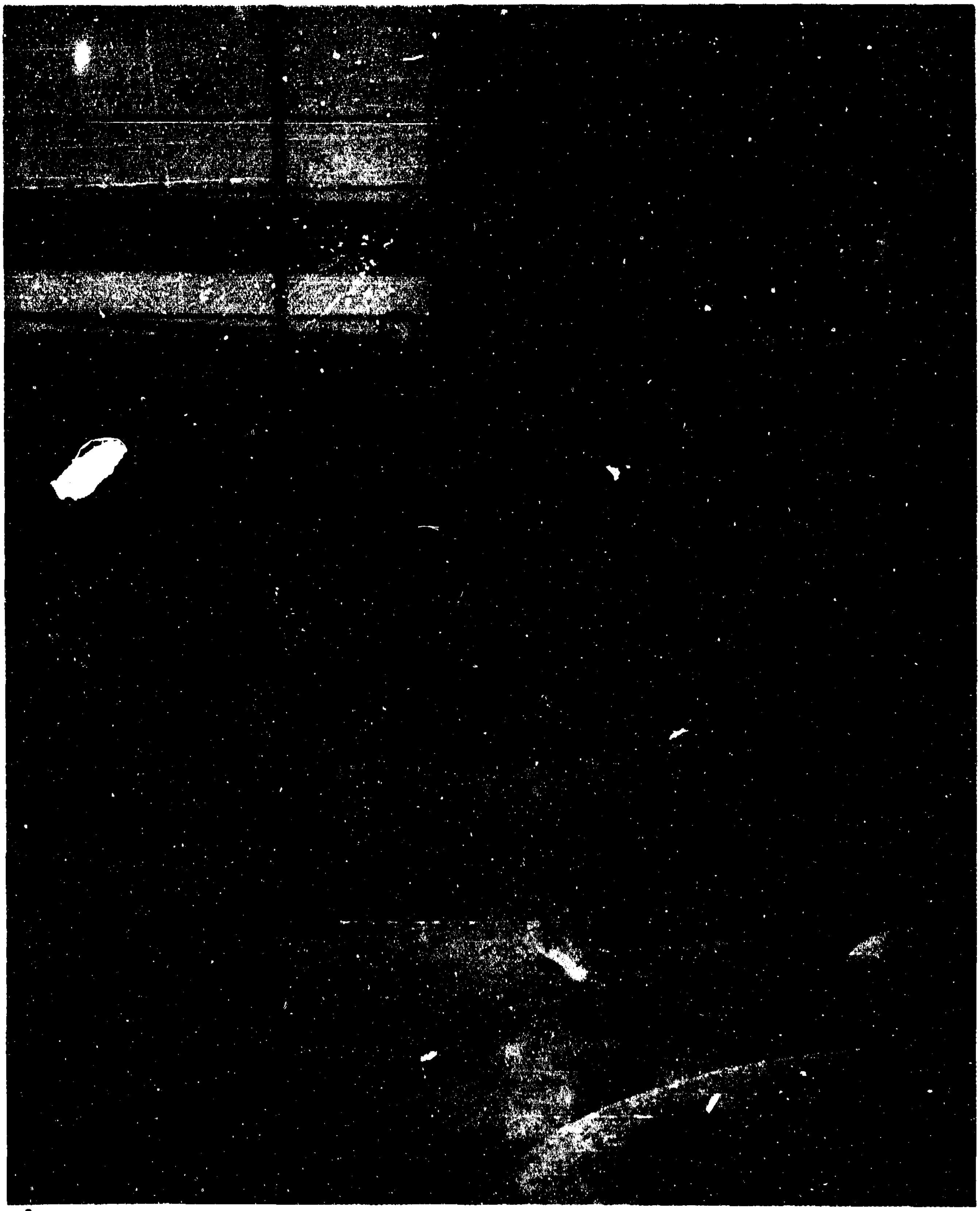
AA-CR-175-213..-1. USS INDEPENDENCE (CVL22). Port passage, second deck, in way of crews galley. Note bulging of ventilation ducts. Vertical duct at right of photograph is of resistance seam welded construction.



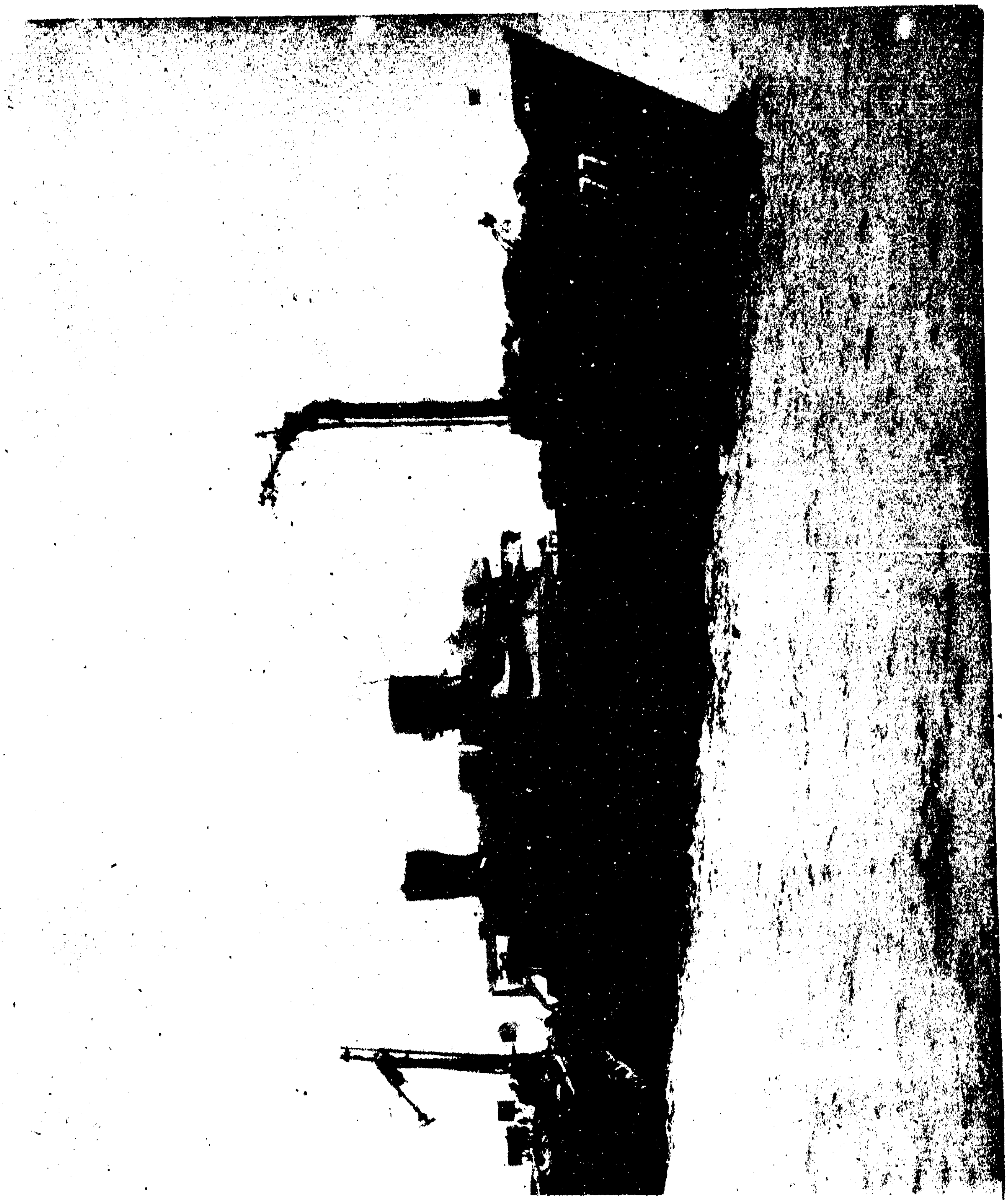
AA-CR-59-2165-11. USS INDEPENDENCE (CVL22). Damage to welded antiaircraft gun sponson and gallery walkway. Port side, looking forward.



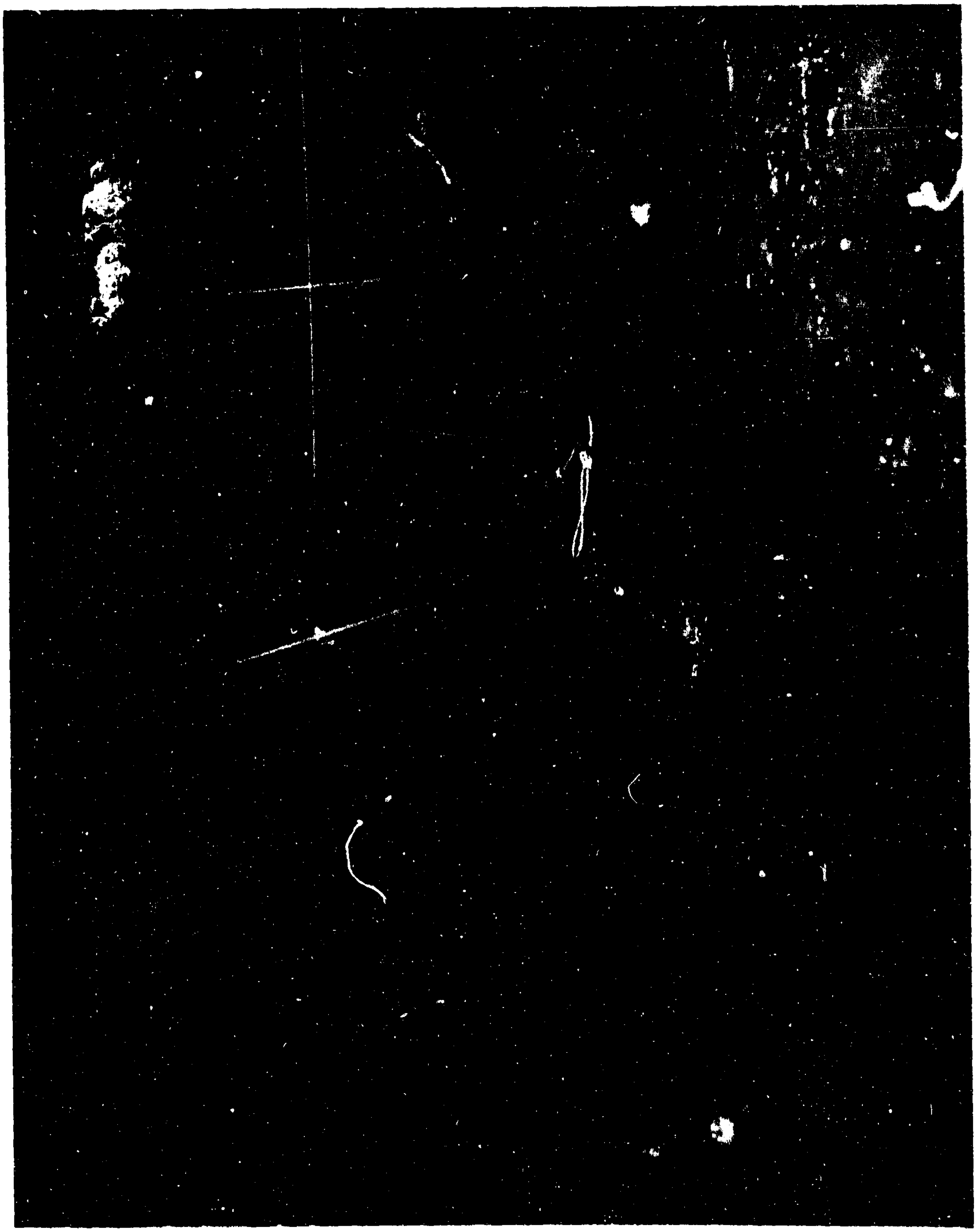
AA-CR-59-2164-5. USS INDEPENDENCE (CVL2 .). Fracture in welded sprinkler supply line in way of flight deck expansion joint. Looking upward.



AA-CR-82-1823-2. USS BUTTE (APA68). Damage to acetylene cylinders by fire. Note exploded cylinder. Cylinder stowage on superstructure deck in way of shipfitters shop. Port side, looking inboard and aft.

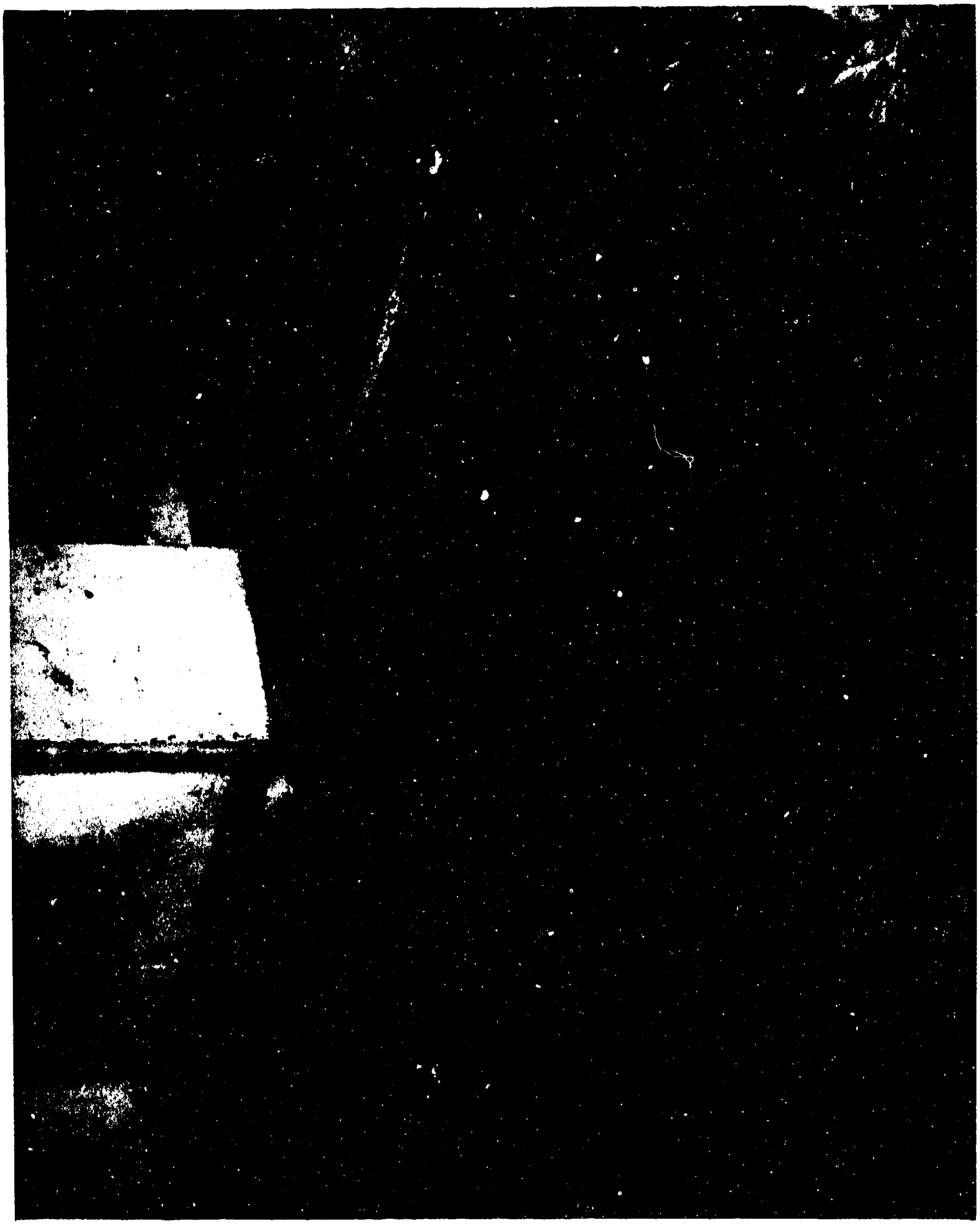


AA-CR-227-49-117. USS CRITTENDEN (APA77). General view of blast damage to superstructure- starboard bow view.



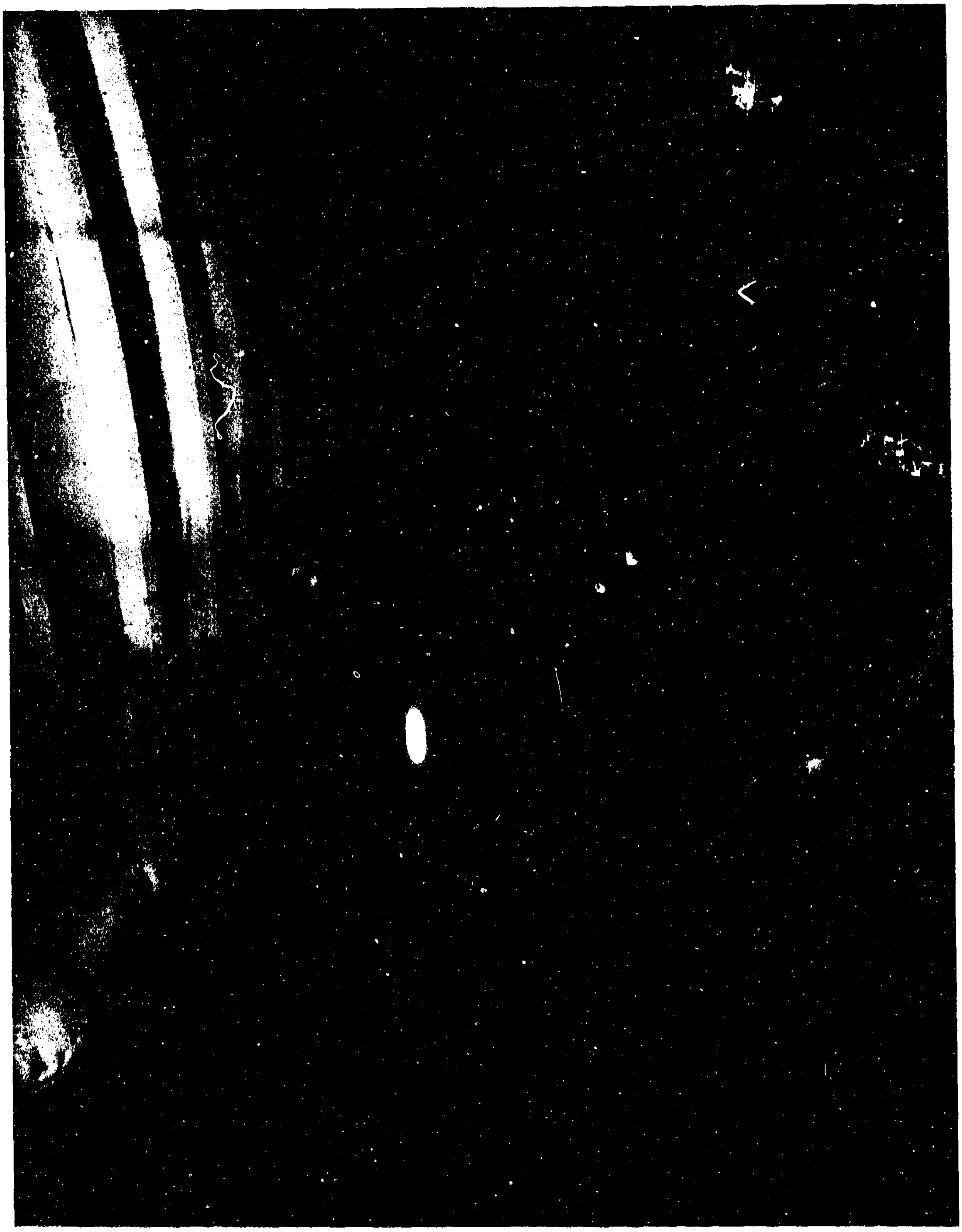
AA-CR-59-2086-4. USS CRITTENDEN (APA77). Deflection of main deck in way of forward hold. Starboard side, looking aft. No failures observed in submerged arc welded butts and seams in deck plating.

AA-CR-59-2086-5. USS CRITTENDEN (APA77). Deflection of upper deck structure in way of forward hold on starboard side. Looking to starboard. Deck plating is submerged arc welded and deck framing is manual arc welded.



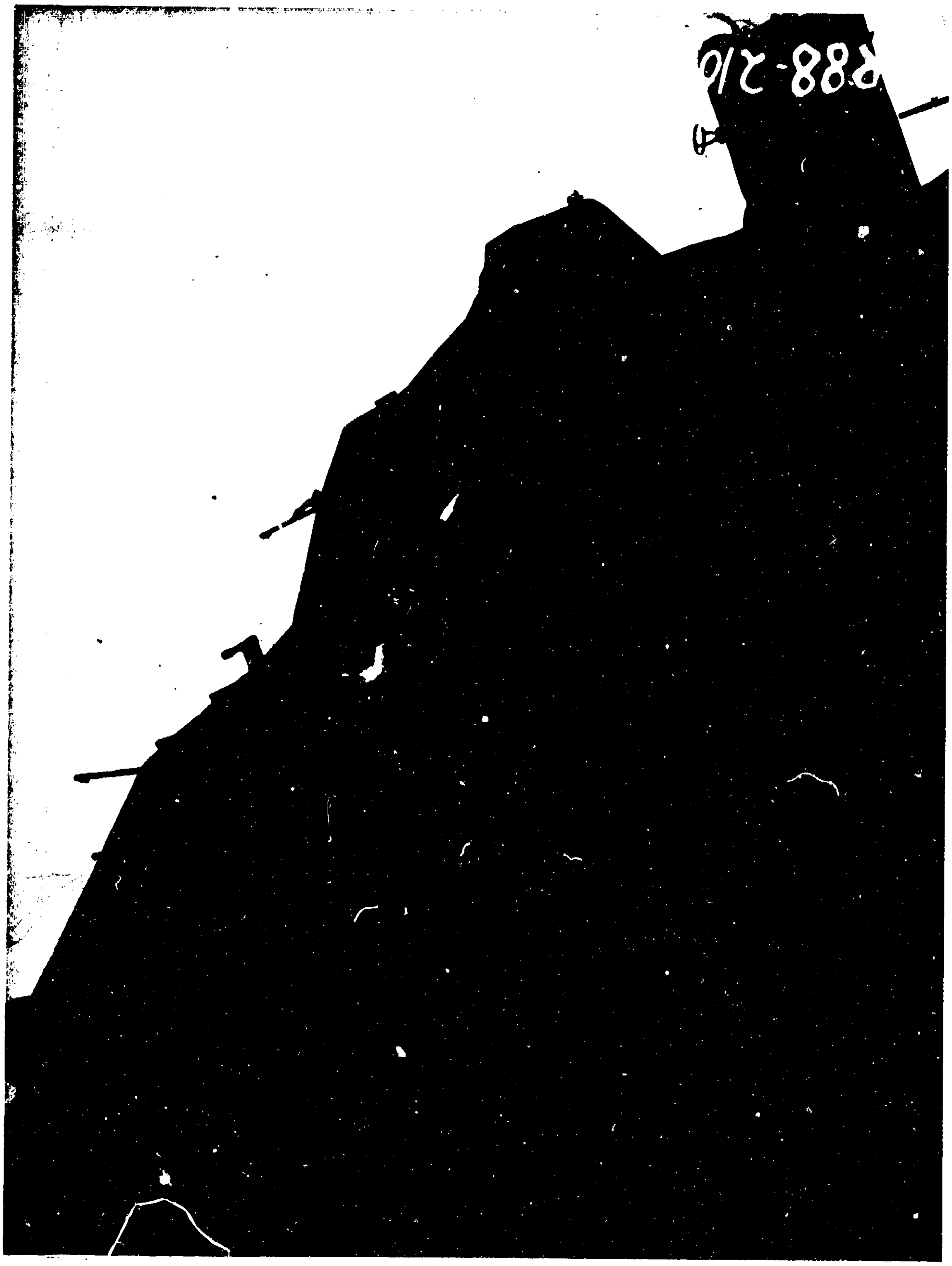
AA-CR-59-2086-2. USS CRITTENDEN (APA77). Fractured weld joining main deck to column supporting longitudinal hatch girder. Starboard side in way of after bulkhead, forward hold. Downward deflection of deck under blast caused failure.

AA-CR-59-2086-3. USS CRITTENDEN (APA77). Fracture in weld joining main deck to column supporting starboard longitudinal hatch girder. Just aft of bulkhead 40 in way of forward hold. Similiar to failure on photograph 2086-2.

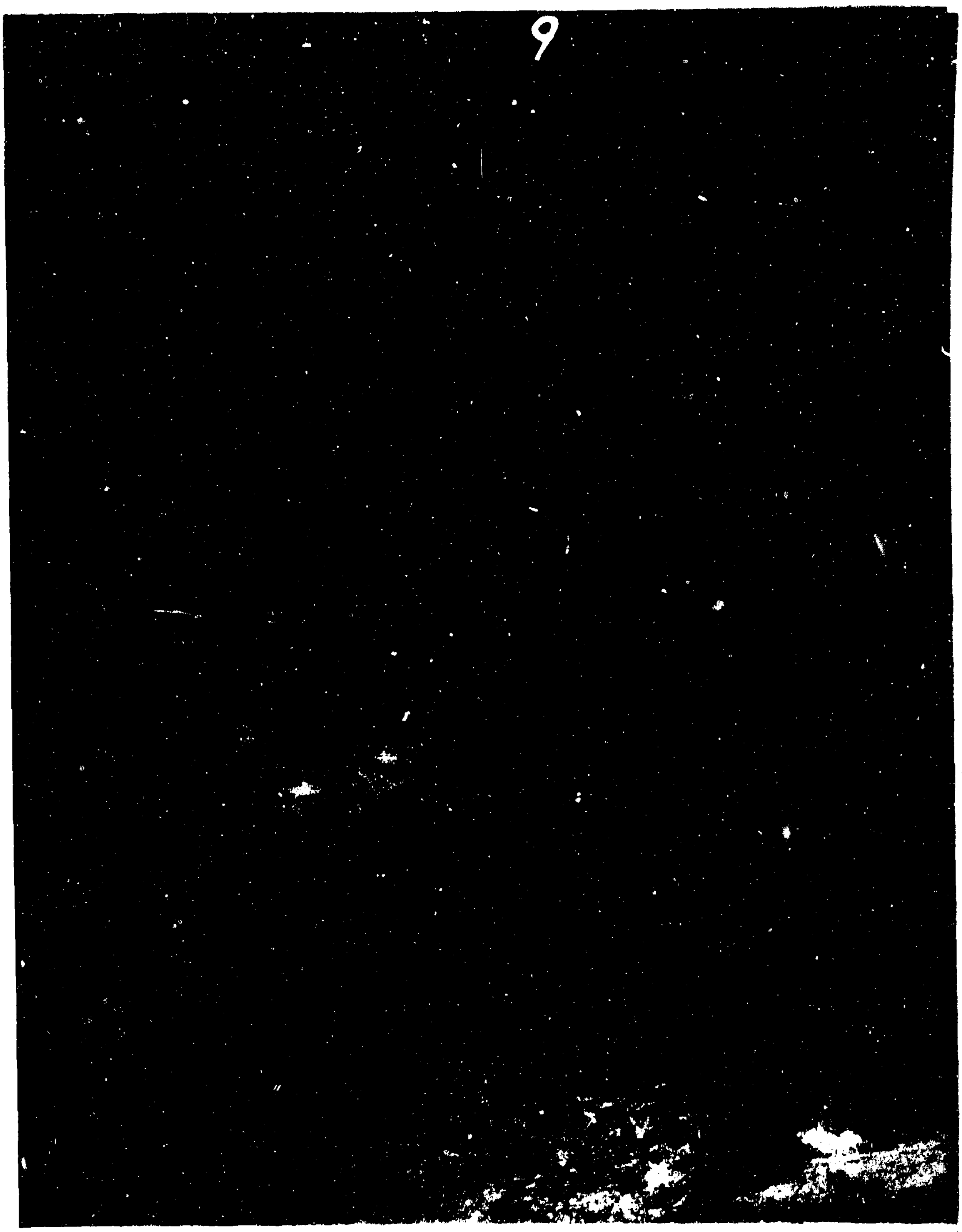


AA-CR-59-2086-8. USS CRITTENDEN (APA77). Deflection of overhead main deck structure in way of forward hold. Starboard side, first platform looking forward. Deck structure all welded.

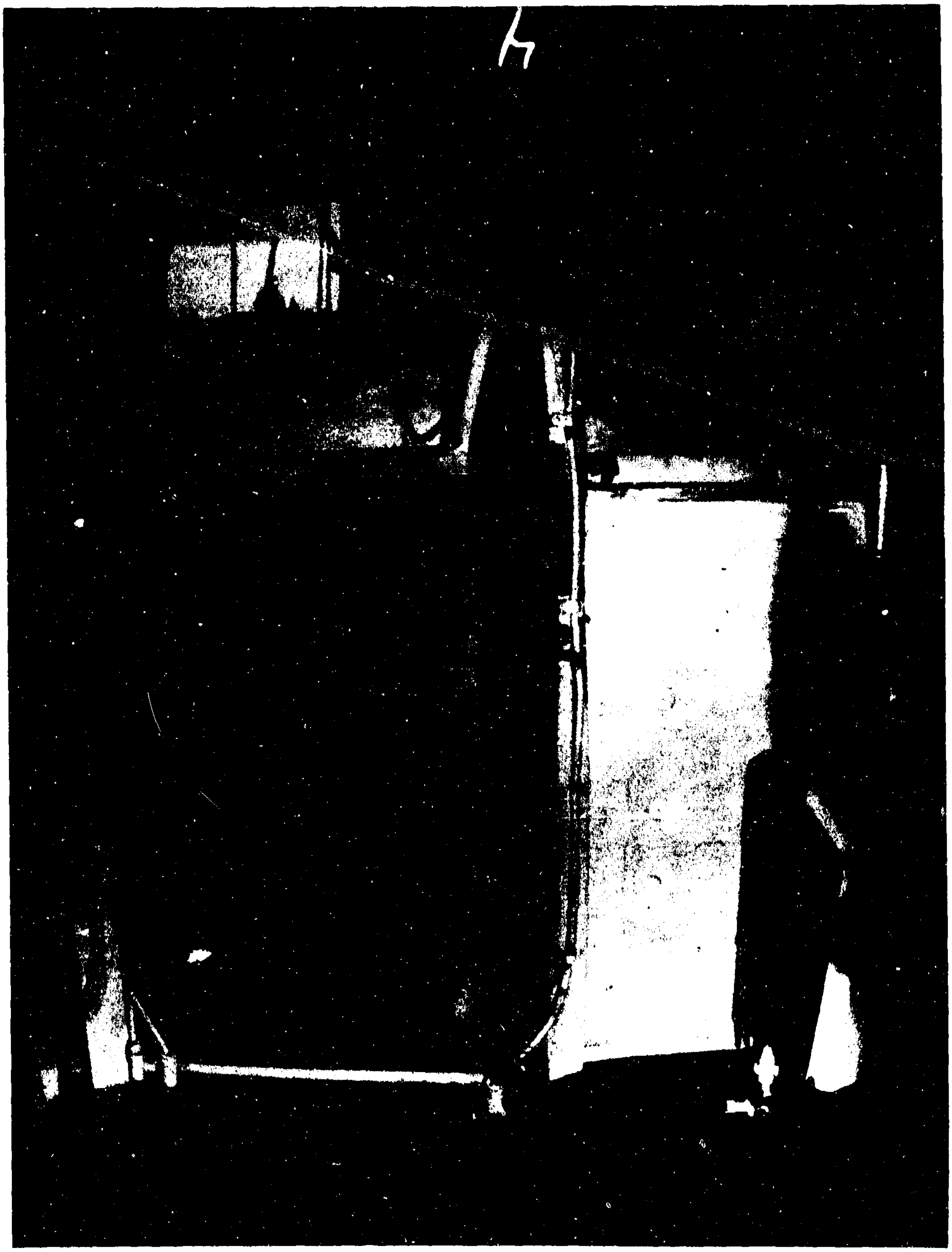
AA-CR-80-1907-1. USS CRITTENDEN (APA77). Failure of welds connecting anti-aircraft director foundation to after deck house. Looking to port.



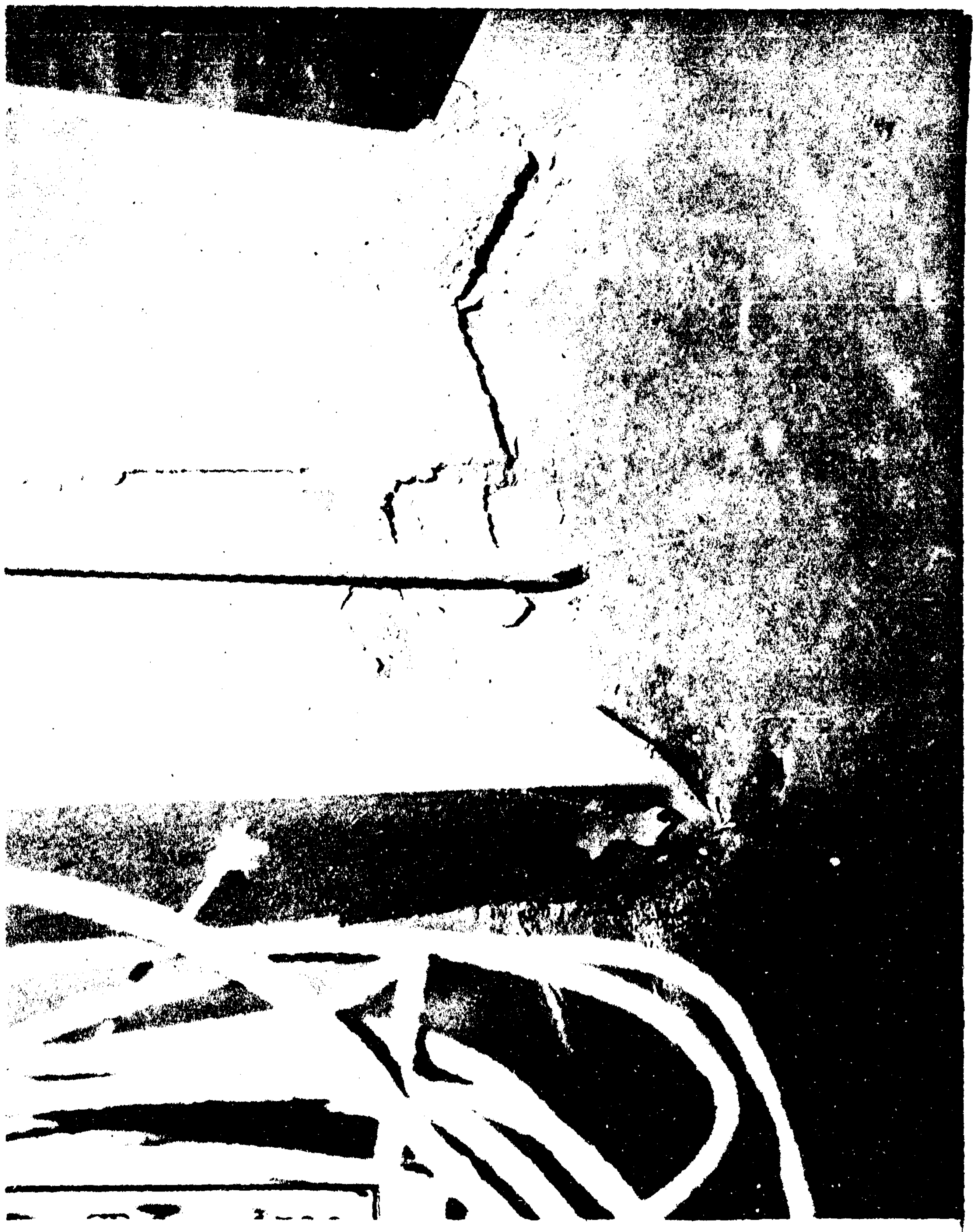
AA-CR-88-2102-2. USS CRITTENDEN (APA77). General view of damage to bridge and forward superstructure. Looking aft, upward and to port.



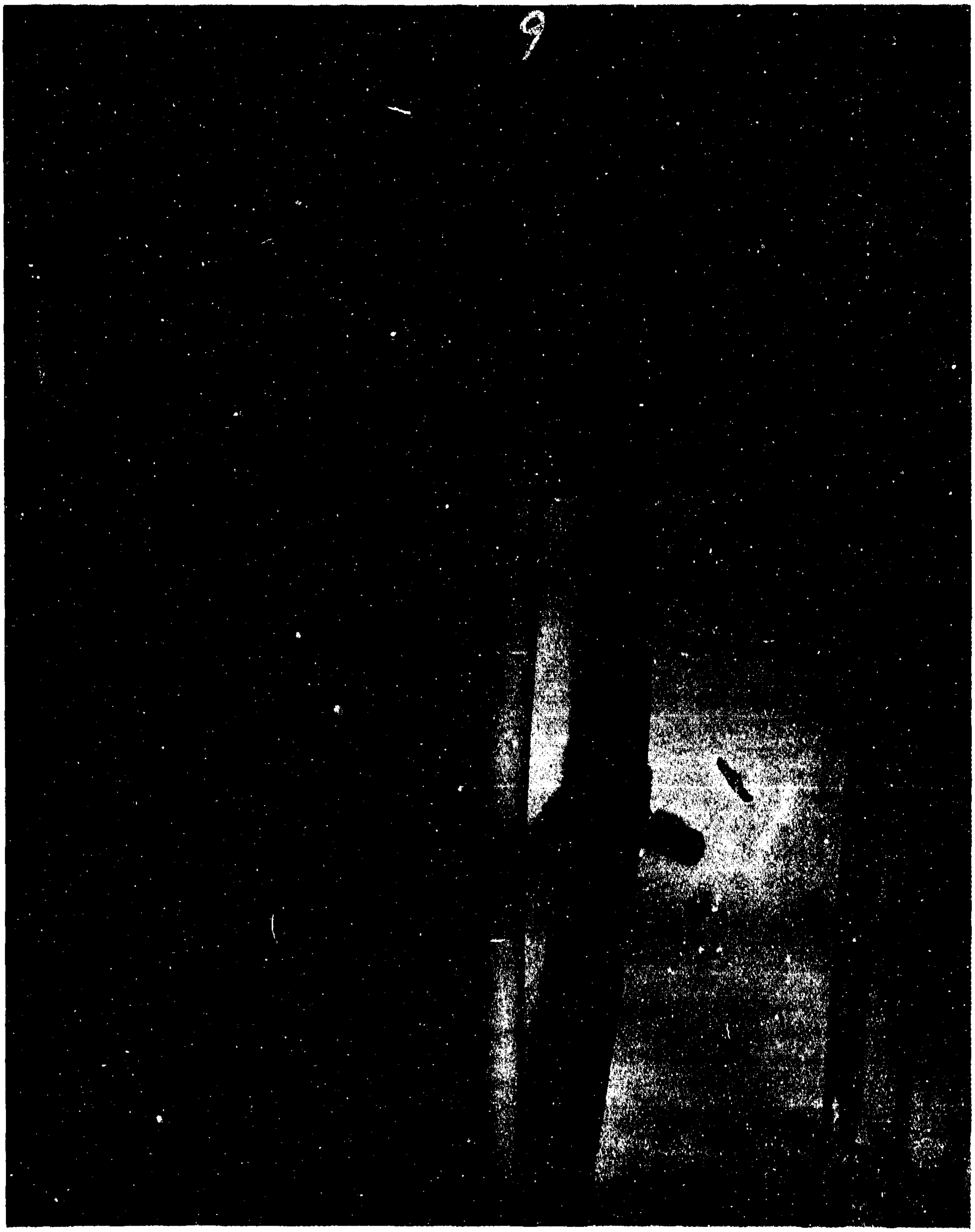
AA-CR-59-2058-6. USS CRITTENDEN (APA77). Damage in way of welded construction near bulwark connection. Port side, on navigating bridge. Austenitic welds in STS plating.



AA-CR-59-2058-4. USS CRITTENDEN (APA77). Failure of austenitic weld in vertical seam in STS plating. Forward bulkhead in Pilot House, looking forward. Note failure in horizontal stiffener.



AA-CR-92-1782-1. USS CRITTENDEN (APA77). Failure of welds joining vertical angle to outboard edge of deck, starboard side. Looking outboard and forward.



AA-CR-92-2086-6. USS CRITTENDEN (APA77). Satisfactory performance of fillet welded stiffeners on badly bulged bulkhead 40. Starboard side, looking aft.

AA-CR-59-2112-11. USS CRITTENDEN (APA77). Failure of welds joining hatch coaming bracket to upper deck in way of forward hold. Deflection of weather deck under blast caused failure.

AA-CR-68-1753-3. USS SKATE (SS305). General view of topside damage. Port side.

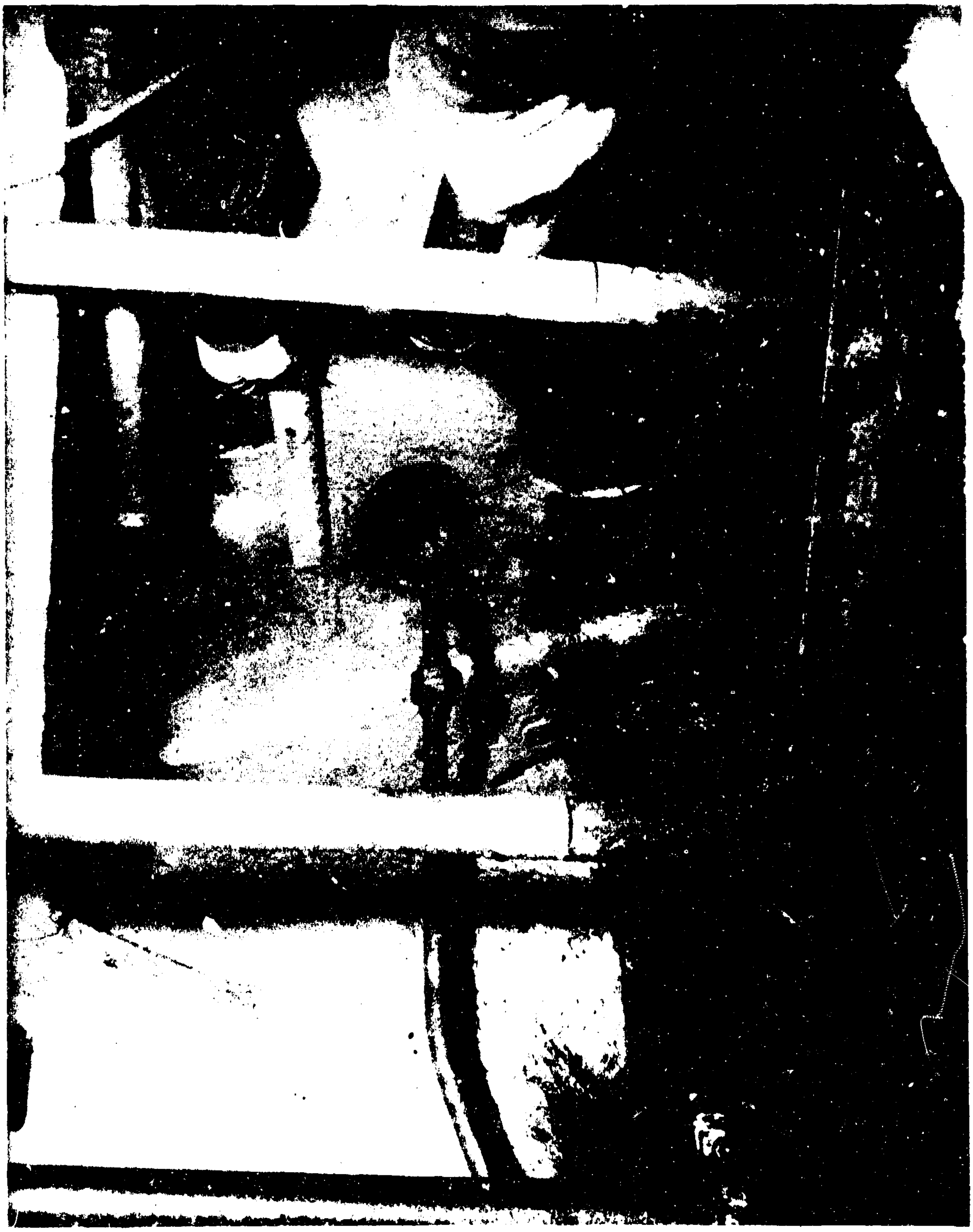
AA-CR-59-2011-9. USS SKATE (SS305). Looking forward at failure of fillet weld joining shell frame to pressure hull just aft of conning tower.

AA-CR-68-1751-11. USS SKATE (SS305). Failure of weld in housing in periscope shears. Looking forward.

AA-CR-68-1752-12. USS SKATE (SS305). Failure of austenitic welds in STS superstructure plating.

AA-CR-59-2057-6. USS SKATE (SS305). Failure of welded connection to silicon bronze outboard induction valve, and socket brazed joint in salt water cooling line. Workmanship defective on both joints.

AA-CR-59-2057-11. USS SKATE (SS305). Copper nickle salt water cooling line pulled from brazed socket connection in make up flange. Workmanship faulty.

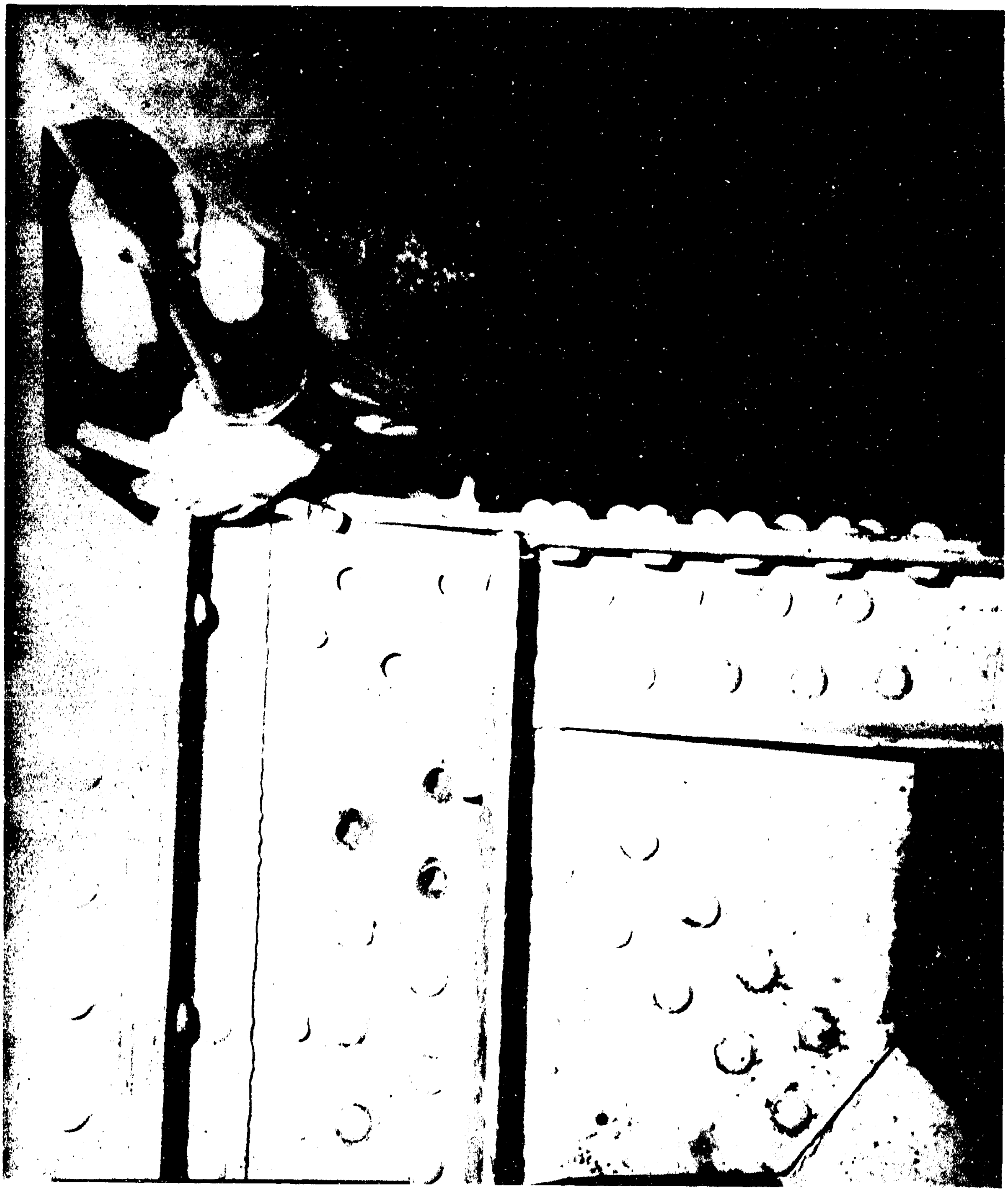


AB-CR-82-4225-12. USS PENSACOLA (CA24). Fracture in web of supporting bracket of cast iron L.P. turbine casing underwater shock damage.

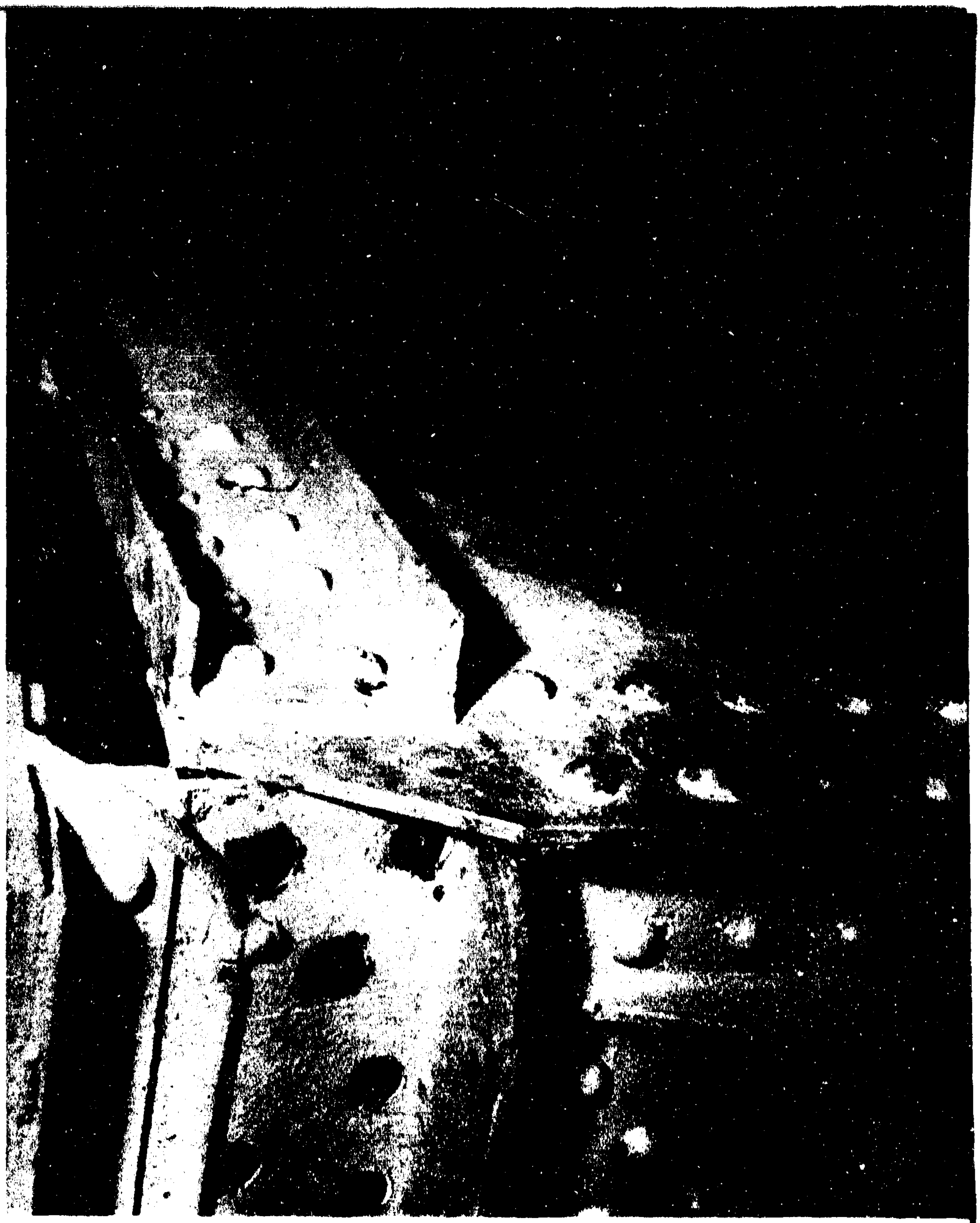
AB-CR-82-4225-8. USS PENSACOLA (CA24). Fracture in web of supporting bracket of cast iron cruising turbine reduction gear casing. Underwater shock damage.

AB-CR-68-1690-11. USS PENSACOLA (CA24). Fracture in flange and mounting bracket of No. 4 cast iron L.P. turbine casing. Underwater shock damage.

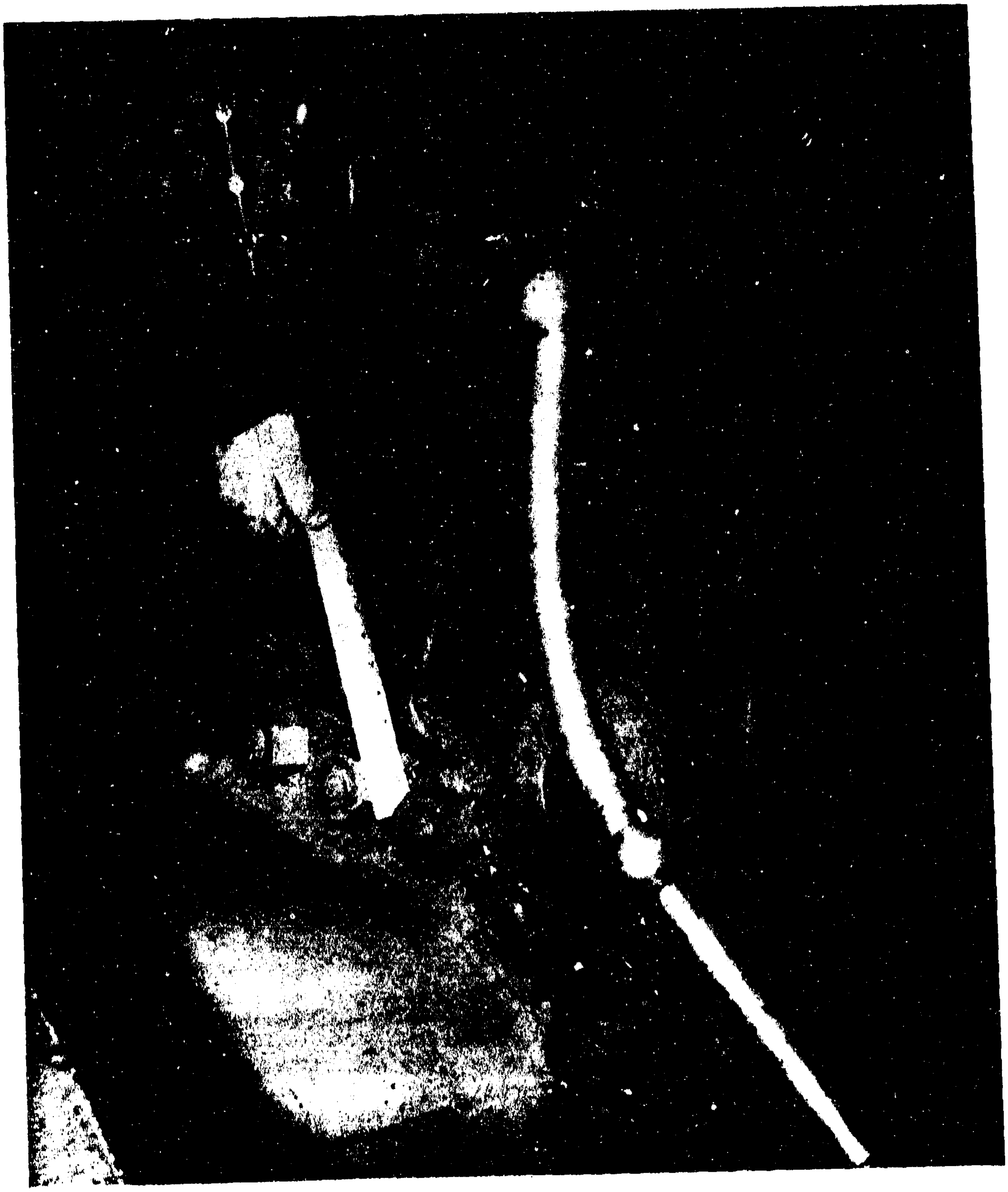
AB-CR-68-1691-8. USS PENSACOLA (CA24). Failure of port main condenser foundation due to underwater shock. Note sheared rivets. Forward engine room, forward face of after end of foundation.



AB-CR-68-1691-5. USS PENSACOLA (CA24). Failure of forward end of port main condenser foundation due to underwater shock. Note sheared rivets.

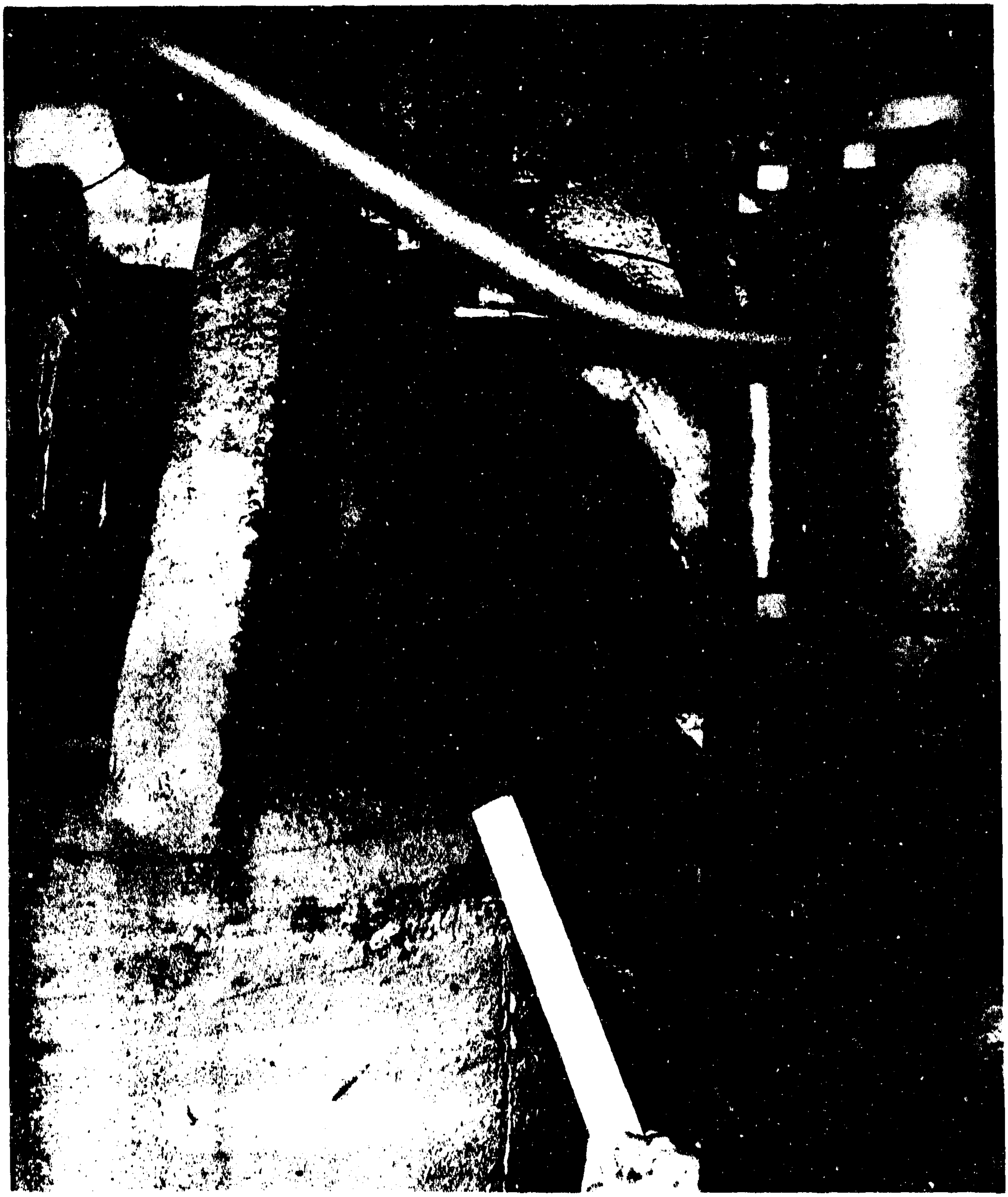


AB-CR-68-1690-5. USS PENSACOLA (CA24). Failure of starboard after corner of starboard main condenser foundation due to underwater shock. Note holes where rivets have sheared.



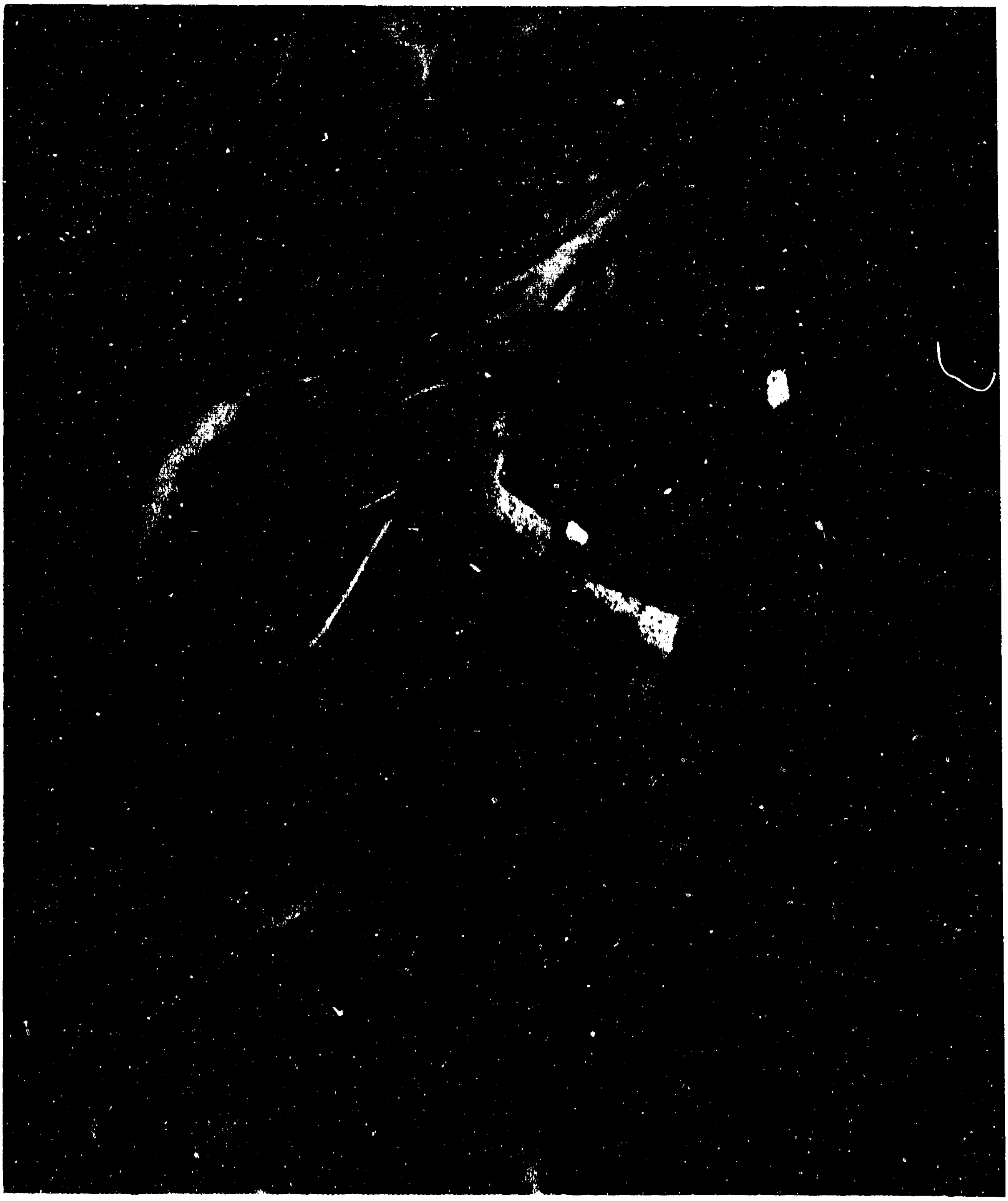
AB-CR-82-4226-1. USS PENSACOLA (CA24). Fracture in cast iron web in No. 1 L.P. turbine. Shock damage.

AB-CR-82-4226-2. USS PENSACOLA (CA24). Fracture in cast iron mounting feet of No. 1 L.P. Turbine. Shock damage.

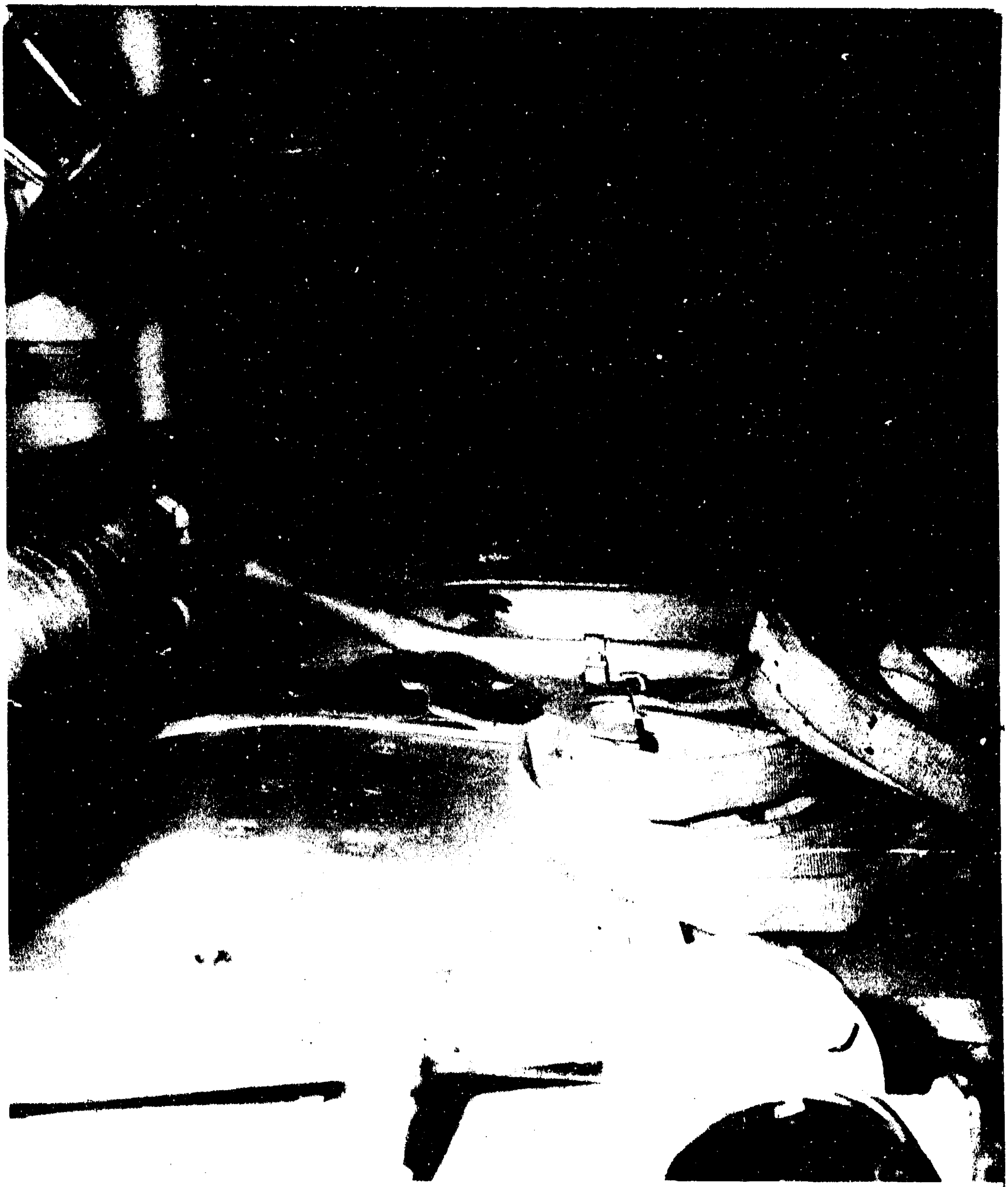


AB-CR- 82-4226-3. USS PENSACOLA (CA24). Fracture in astern cast iron casing near support, No. 1 L.P. turbine.

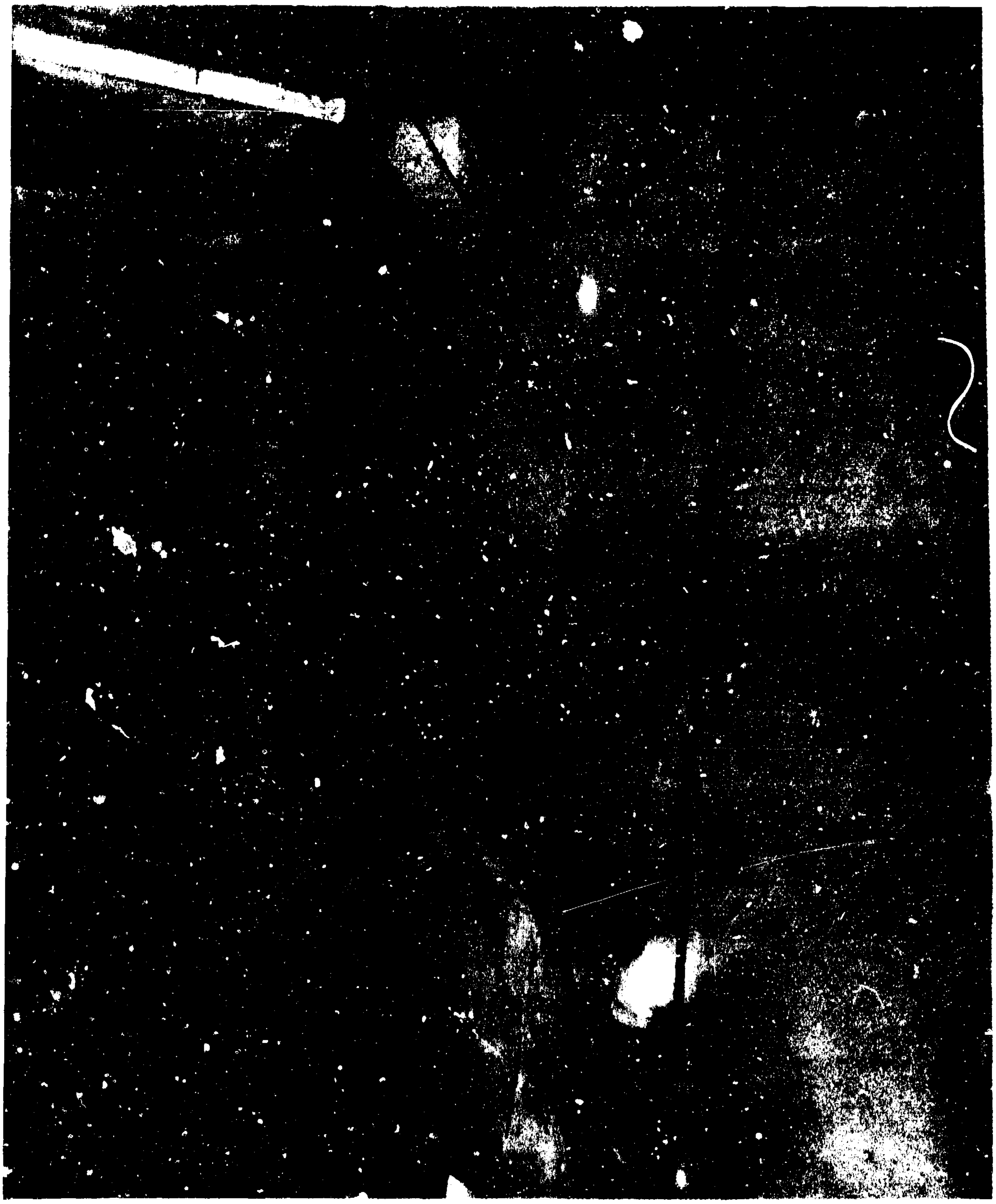
AB-CR-82-4226-5. USS PENSACOLA (CA24). Fracture in cast iron bracket and flange of casing on aft end of No. 4 L.P. turbine. Shock damage.



AB-CR-82-4226-6. USS PENSACOLA (CA24). Fracture in cast iron mounting bracket, No. 4 L.P. turbine. Shock damage.



AB-CR-80-2195-7. USS FALLON (APA81). Transverse bulkhead bulged by underwater shock. Note end welded pins securing fibre glass insulation still holding athwartship passage frames 65 to 68, first platform, looking to port



AB-CR-80-2196-7. USS FALLON (APA81). Longitudinal bulkhead damaged by underwater shock. Note performance of end welded pins securing fibre glass insulation to bulkhead. Frames 56 to 60, looking forward and to starboard.

AB-CR-76-2083-11. USS FALLON (APA81). Failure of welded connection at intersection of deck longitudinal with transverse structural bulkhead. Underwater shock damage. Bulkhead 124, looking forward and upward from main deck.

AB-CR-76-2083-5. USS FALLON (APA81). Failure of welded connection at intersection of decks longitudinal and transverse structural bulkhead 124. Underwater shock damage. Looking upward, forward and to port from main deck.

SECRET

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Defense Special Weapons Agency
6801 Telegraph Road
Alexandria, Virginia 22310-3398

TRC 4 April 1997

MEMORANDUM TO DEFENSE TECHNICAL INFORMATION CENTER
ATTN: OMI/Mr Bill Bush

SUBJECT: Declassification of Documents

The following is a list of documents that have been declassified and the distribution statement changed to Statement A, Approved for Public Release.

XRD-41, AD-366731
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XRD-40, AD-366730
XRD-39, AD-366729
XRD-38, AD-366728
XRD-34, AD-366720
XRD-13, AD-366725
XRD-8, AD-366699
XRD-5, AD-366697
XRD-6, AD-366698
XRD-21, AD-366708
XRD-27, AD-366714
XRD-22, AD-366709
XRD-26, AD-366713
XRD-28, AD-366715
XRD-29, AD-366727
XRD-36, AD-366722

If you have any questions, please call me at 703-325-1034.

Ardith Jarrett
ARDITH JARRETT
Chief, Technical Resource Center